Health and Welfare
Canada

Santé et Bien-être social
Canada

Canada

PREVENTIVE DENTAL SERVICES
second edition

A Report Prepared on Contract for the
Department of National Health and Welfare

PREVENTIVE DENTAL SERVICES

SECOND EDITION

A Report Prepared on Contract
for the
Department of National Health
and Welfare

Published by authority of the
Minister of National Health and Welfare

Également disponible en français sous le titre
"LA DENTISTERIE PRÉVENTIVE"

Minister of Supply and Services Canada 1988
Cat. No. H39-4/1988E
ISBN 0-662-16423-7

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FOREWORD

This report, Preventive Dental Services, Second Edition, is a comprehensive review of the many dental services provided in Canada which focus on prevention rather than treatment of dental diseases. The report is directed primarily to educators, students and practitioners in the dental health field. Nevertheless, it will be of value as a reference guide to all health professionals and others interested in the prevention of dental diseases. The report's true value lies in its highly professional review and analysis of the research literature written by some of the best researchers in the field. Current recommendations for practice and research are based upon its sound foundation.

The report, Preventive Dental Services, is part of a national program to develop guidelines and conduct research studies in the area of dental health services. Information on other reports and working groups can be obtained from the adviser on dental health standards.

The present report replaces the 1979 report, Preventive Dental Services: Practices, Guidelines and Recommendations, prepared by the Working Group on Preventive Dental Services.

Due to the considerable interest in the first Preventive Dental Services Report and the 1980 report Oral Radiological Services, an evaluation of these two reports was conducted on contract by Dr. D.W. Lewis and completed in August 1983. After a review of this evaluation a contract was signed to revise, update and condense both the 1979 report on Preventive Dental Services and the 1980 Oral Radiological Services report. The goal of condensing or reducing the size of the preventive report seemed almost an insurmountable task in view of the many topics to be covered, and although considerable effort was made in this direction, the present report is somewhat longer than the original report in the number of words. The laser printer used for this edition resulted in fewer pages of text.

Dr. D.W. Lewis, who chaired the Working Group on Preventive Dental Services and subsequently became the contractor for this update, worked with almost 30 researchers to produce both the preventive and radiology reports. His efforts to coordinate, review, edit and compile the reports over a period of more than two years are greatly appreciated. In addition to the above-noted responsibilities, Dr. Lewis also authored and co-authored some of the chapters.

Up until recently, preventive dental services have focused on the young and the present report is reflective of this tradition. Although an attempt was made to address the research literature on preventive dental services by age group and in particular for older persons, it was not considered an easy task and seemed best to leave to another specially assigned group which was already in the planning stages. It is hoped that two new groups will be addressing issues related to older persons: one on dental health services and promotion for seniors and the other on dental health care and promotion in institutions.

Another topic which has not been addressed to any significant extent and yet is of growing importance is dental health promotion. A separate initiative will address health promotion for dental health professionals.

Professional reviews of draft chapters by Health and Welfare Canada officials and others, editing and translation were all undertaken by and/or through the adviser on dental health standards. A list of the primary departmental reviewers appears on the next page and a sincere expression of appreciation is directed to these individuals.

This is a report to the federal government and does not represent a policy statement of the federal government.

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Final report received September 1986
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4. J. McGhie and E. Lewis provided most of the extensive typing, word processing and photocopying services necessary for the drafting of this report prior to submission to Health and Welfare Canada.

5. I am greatly indebted to all of the above persons but most of all to Sharon Amer, Adviser, Dental Health Standards, Health Services Directorate, Health Services and Promotion Branch, Department of National Health and Welfare, for her advice and support throughout this project.

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CHAPTER 1

CHAPTER 1

INTRODUCTION

It is over seven years since a working group,[1] arranged by the Health Services Directorate[2] of the Department of National Health and Welfare, produced a report entitled Preventive Dental Services; Practices, Guidelines and Recommendations which reviewed and made recommendations concerning preventive dental services in Canada. This report was published by the Department in 1980 and since then has undergone six reprintings. It has been distributed widely both nationally and internationally to dentists, dental hygienists, dental public health and other dental personnel, dental hygiene and dentistry teachers and their students. In 1983 an external evaluation of the report's impact on increasing the knowledge and reinforcing and changing the current practices of its recipients was positive and favourable.

In response to these positive outcomes and the report's popularity, as well as the realization that a lot can happen in such a field over a period of seven years, the decision was made to update the report. Rather than using another working group, the update, along with that of a companion publication of the Department on oral radiological services, was accomplished through a contract between D.W. Lewis and the Minister of the Department of National Health and Welfare. This arrangement resulted in the identification of primary authors, each an expert in his/her field, to prepare Chapters 3 to 11, and of similarly qualified persons to provide the critical, scientific reviews of each of these chapters. The names, positions and addresses of the chapter authors and the reviewers are listed on previous pages. Their important contribution to the preparation of this report is again acknowledged here.

One inevitable consequence of having ten different authors is that writing styles will differ. Although editorial standardization of spelling, headings, sub-headings and table format, etc. among the chapters has been imposed, no attempt has been made to re-write chapters to one common style. The annoyance this may create for some readers is much less than the anger that the authors whose sacrosanct writing style is changed would heap upon a meddling editor.

The coverage of material in the present report is similar. Indeed, except for some reorganization, the chapter topics reviewing the effectiveness of selected preventive methods are identical to those of Part II of the 1979 report.

The one composite chapter on Combinations of Preventive Methods remains. For nearly all of the remaining chapters, the traditional categorical approach in which each preventive topic is reviewed independently is used. Readers, while appreciating the administrative convenience of this format, will recognize the need to integrate all of this material since, as in rendering care, all of the present and future problems and preventive needs of each patient as a whole must be considered.

Authors of the various chapters often mention the special needs of high-risk patients. No emphasis, however, has been placed on older adults. Future demographic and oral health status changes have some very interesting and important implications for the preventive dental needs of middle-aged and elderly persons. This subject is discussed further in Chapter 2. Because the published research literature does not comprehensively address the preventive dental needs for this group, Chapters 3 to 11 do not cover well specific preventive procedures for the older adult population. The subject, however, is too important to ignore. It would be useful to establish a special study or working group to bring together in a dental context, the social, economic, behavioural and epidemiologic aspects, and the preventive and therapeutic needs of this group. This review would especially include the epidemiology, diagnosis, prevention and therapy of root caries.

---

[1] Members of the working group were: Dr. D.W. Lewis, Chairman (Toronto); Dr. J.T. Boulton (Calgary); Dr. R.C. Burgess (Toronto); Mrs. P.M. Johnson (Aurora); Dr. D.P. Kandelman (Montreal); Dr. K.A. Newman (Vancouver); Dr. R.G. Romcke (Charlottetown); Dr. J.W. Stamm (Montreal). The secretariat was Mrs. S.B. French (now Amer)(Ottawa).

[2] Formerly the Health Standards Directorate.

Some changes in the focus of this report have been made. One difference is the heavy emphasis given to the belief that recent changes in oral health status will affect the practice of preventive dentistry. Large decreases in dental caries incidence among children in developed countries are well recognized today. For example, the decline over the past 10-15 years in average DMF dental caries scores in children of various ages living in different regions of Canada has ranged from about 33-50 per cent and, in contrast to earlier times, many children today have never experienced any decay. Only part of this decline is due to water fluoridation and to the direct in-office preventive activities of dental personnel. Much of it is apparently attributable to factors such as the use of fluoride dentifrices outside the dental clinical environment. Whatever the source, these downward trends have great implications for the general use of professionally applied cariostatic preventives that dental personnel must take into account if patients' interests are to be well served. The discussion of this begins in the next chapter, where concerns about the duplication of preventive efforts and the need for targeting on high risk are discussed. These themes, especially the need for high-risk targeting, frequently recur in later chapters.

A second change in focus is a greater emphasis on evidence in many chapters. Authors were encouraged to base their chapter reviews and recommendations about the most effective preventive procedures and their frequency of use as much as possible on well-designed, randomized, controlled clinical trials. Such studies use proper, contemporaneous comparison groups and, consequently, give the highest level of evidence to support or reject the adoption of the particular procedure being assessed. This is the essence of the scientific approach to clinical decision making. Prospective dental patients and conscientious dental personnel deserve nothing less than to have the treatment they receive or provide based on the highest level of evidence.

Unfortunately, and this may be a surprise to some, the highest level of evidence is not always used to guide preventive and therapeutic procedures in medicine and dentistry. Too often, case reports which do not involve a proper or, usually, any control group and anecdotal information are the primary basis for treatment decisions. However, in preventive dentistry, randomized, controlled clinical trials are used much more frequently and all of the major preventives have been tested in this way, as the attached chapters show.

Despite this generally high research standard, the stated needs for further research into surprisingly fundamental questions in nearly every chapter show that much is still to be learned. Surprisingly, a comparison of the research needs stated in the 1979 report with those expressed in the present one shows little change. Except for recent confirmation by a number of randomized trials that a professional prophylaxis prior to topical fluoride application is not essential as it does not provide additional caries protection, there really have been very few new discoveries despite all the research activity.

This Preventive Dental Services Report was written in 1985/86 while the earlier one was completed in 1979. Throughout the text of this new report reference is frequently made to terms such as the "original" or "earlier" or "initial" or "working group" report and to the year 1979. Readers should realize that these terms refer to the 1979 working group report on Preventive Dental Services which the present report attempts to summarize, update, and, respectfully, replace.

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CHAPTER 2

CHAPTER 2

RECENT CONSIDERATIONS ABOUT PREVENTION AND DENTAL DISEASE

D.W. Lewis

The importance and benefits of the prevention of dental disease are well established and secure. Although the debate about the virtues of prevention versus therapeutic care has not entirely subsided, recognition that both are necessary and should function in an integrated manner seems to have been established (1,2). Thus, this chapter is not about the importance of dental prevention. The case for prevention has already been made and needs no further supportive arguments here.

In the following chapters the effectiveness of selected dental procedures are reviewed. This chapter is much more general. It briefly examines recent considerations about the costs of prevention and preventive strategies, and a new definition of prevention. The implications that the changing burden of dental disease have for future preventive needs and practices are also described.

2.1 PREVENTION

In the 1979 report (3) the factors influencing the practice of preventive dentistry and the utilization of preventive dental practices by dental personnel were reviewed in detail. It was reported that factors such as the teaching in dental educational institutions and continuing education programs, peer group standards, reimbursement arrangements, governmental and non-governmental program guidelines and standards, and commercial advertising are influential. Preventive practices by dental professionals were characterized as being highly variable within and among geographic regions and low in frequency per patient, on average. In Canada, about 10-15 per cent of all dental services completed by dentists and their staff were preventive, usually prophylaxis and topical fluoride applications.

There is very little recent research to support changes in these 1979 conclusions, although the impact of the dental literature as a factor in the uptake of new preventive procedures (4) and documentation of a slightly greater utilization of preventive procedures by dental professionals, at least in the United States (5), could be added.

Recently, the cost-containment aspects of the prevention of oral disease have been thoughtfully analyzed (6). From this simulation study, strong support for water fluoridation to save treatment costs emerged, along with regular professional periodontal care in adulthood. However, if maximum oral health benefits and cost-containment are to be realized, the authors emphasized that the costs of these periodontal services must be reduced by lower fees, or the use of personnel other than the dentists, and/or new, more efficient delivery systems (6). Thus, the full cost-containment potential of dental prevention cannot be assessed independently of the policies governing the educational and delivery systems. Nor can the impact of dental prevention as delivered by dental professionals be separated from a whole host of factors outside the control of dentistry, as the recent decline in dental caries in developed countries seems to suggest so eloquently. And, as with the greater use of nurse practitioners to provide preventive medical counselling (7), there may be an escalation rather than a saving in total costs if, for example, the potentially lower costs due to the greater use in preventive activities of personnel other than dentists do not result in lower fees and/or the need for fewer dentists to be trained.

None of the foregoing things is said as a negative comment about prevention but to emphasize, as was done in the 1979 report, that prevention despite all its benefits can be costly and, therefore, must be used judiciously and selectively. As stated by Holtzman (in a broader context than is emphasized here), the prospects for prevention are often less than what is promised (2). The conscientious, careful dental practitioner's goal should be to prove this statement to be false by properly using only preventive agents and procedures shown to be efficacious in randomized clinical trials on carefully selected, high-risk patients at appropriate intervals. However, the less cautious practitioner who provides non-efficacious or, even, efficacious preventive dental services non-selectively and excessively will prove it to be true, although he/she and his/her patients may never realize it.

To provide preventive dental services appropriately (i.e. effectively and efficiently), a strategy is required. Looking only at the target person and service side, a successful strategy can be outlined by a few simple questions. Who needs what specific preventive services, and with what frequency are they needed? And, having identified those persons who need a particular preventive service, how, if necessary, can their utilization at the desired frequency be enhanced? The first set of questions -- particularly what services and their frequency -- are, essentially, the subject of the remaining chapters in this report. Because all of the needed research has not been done, it will be found that some of the essential answers are still not available. Regarding the second set of questions, the current lack of ability to identify accurately those at high risk to dental disease is lamented by many of the authors of the ensuing chapters, although some general hints arising from dental caries epidemiology can be found in Chapter 3. The essential behavioural research leading to greater and consistent dental utilization by those at high risk is even less well developed.

Because of these deficiencies in knowledge, the prospects for a successful (highly effective) preventive dental strategy are not very good at present. One recent development that helps clarify the situation conceptually by classifying the general application of preventive dental interventions is the new operational definition of disease prevention by Gordon (8). He points out that the older, traditional primary and secondary classification of prevention depends on the ability to identify the biologic origin of disease. This, however, does not really apply to chronic disease that is very common today. Also, primary and secondary imply an ordinal relationship; this may, however, create a conflicting picture. Despite suggestions based on current knowledge about disease epidemiology and cost-effectiveness studies that many primary preventive interventions should be limited to high-risk individuals, the inference that primary prevention is the first or basic level of prevention implies that it should be provided to all. To help resolve the confusion, Gordon has suggested an epidemiologically based, operational classification of prevention.

As seen in Table 2.1, taken from Bruce (9), Gordon classifies prevention into three levels -- universal, selective and indicated -- according to the target or risk group for whom the intervention is intended, the personnel providing it and cost-benefit considerations. In view of the changing epidemiology of dental disease and concerns about costs, it is suggested that this scheme -- or modifications of it that will inevitably arise -- for classifying prevention is the appropriate one for guiding preventive activity in the future. It should replace or be given equal status with the primary, secondary, tertiary classification.

The problem with application of the primary, secondary, tertiary definition of prevention is that it lacks the discriminatory power required of a classification scheme today. Each preventive activity becomes categorized in one of the three groups really on the basis of symptoms without any additional guidance as to the intended target group, the level of professional involvement and personal motivation required, or cost-benefit aspects. These latter considerations are important today because i) dental disease is less prevalent; ii) numerous preventives with similar effects are available; and iii) costs and cost consciousness are high. Gordon's more functional classification attempts to guide rational clinical decision making with these considerations in mind.

TABLE 2.1

GORDON'S CLASSIFICATION OF PREVENTION

Universal Preventive Measures	**Selective Preventive Measures**	**Indicated Preventive Measures**
1. Desirable/ advocated for everyone.	1. Appropriate in pre-disposed individuals, i.e. with above-average probability of contacting disease because of certain epidemiologic factors or characteristics.	1. To be used on high-risk individuals from prior disease experience.
2. Applied without professional assistance -- depend on individual motivation.	2. Depend primarily on individual motivation.	2. Require professional advice/ assistance for optimal results.
3. Benefits outweigh costs and risks for everyone.	3. Benefits outweigh costs and risks only when used as outlined above.	

Source: Bruce, I. (9).

2.2 THE CHANGING BURDEN OF DENTAL ILLNESS

The preventive procedures utilized for patients should match their anticipated individual dental needs, described here as the avoidable burden of dental illness. A detailed review of the epidemiology of the major dental diseases is not provided as other, more appropriate sources exist (10-12). Some of the following chapters do provide epidemiologic information relevant to that chapter's content. For example, the new, general findings in respect to plaque development and the epidemiology of periodontal disease have been included in Chapter 4 because of their relevance to plaque control. A detailed accounting of time- and age-related distributions of dental caries in individuals, teeth and tooth surfaces can be found early in Chapter 3 because of the great implications that this "new" epidemiology of dental caries has for the highly selective use of sealants. The natural history of dental caries and periodontal disease are briefly described in Chapter 11 in relation to an assessment of recall examinations for the early detection of these diseases.

As this limited epidemiologic material and the initial statement in the preceding paragraph emphasize, there should be an intimate relationship between an individual's current and anticipated, downstream dental needs and his/her professionally and personally administered preventive service requirements.

What implications for professionally administered preventive services does the changing burden of dental disease have? The answer to this question requires speculation about the future given what is known now about current oral health status and recent changes in it. These changes are characterized in the developed countries by declines, over the past decade or so, in children's average dental caries scores of about 30-40 per cent, even greater reductions in smooth surfaces caries and great increases in those who have never experienced any decay. Since dental disease incidence is age-related, the preventive implications must also consider demographic changes.

Demography reveals a decline in mortality leading to greater longevity -- the so-called aging of the population. As mortality declines, the opportunity for morbidity increases. However, most analysts feel that the reduction in dental caries observed in young persons today does not merely represent a delay but a 7lifetime reduction in their caries morbidity. These reductions in dental caries and caries-related tooth loss in combination with an aging population will result in an increasingly dentate older population as each new age cohort reaches old age (13). Furthermore, adults of all ages will likely have experienced far less decay than in the past and, even in those with decay experience, the number and extent of their restorations will be much smaller than in the past (14).

Although periodontal disease, particularly in adults, is highly prevalent, close examination of the distribution of individuals' periodontal scores reveals that most periodontal disease is manifest as gingivitis. Severe periodontal disease definitely requiring professional attention (e.g. surgery) occurs in far fewer persons, perhaps 20 per cent of the middle-age and older population (15,16). As well, there is some evidence that the existence of some plaque and calculus is compatible with lifetime tooth retention and maintenance of periodontal attachment through to old age (17).

Well, to repeat the earlier question, what does all this mean for professionally administered preventive services? The following answers, although speculative, appear to be reasonable.

1. Preventive services should be targeted on those individuals, teeth, and tooth surfaces and supporting tissues at high risk; this is consistent with the principle espoused earlier that the preventive service(s) provided must be selected to match each patient's anticipated needs.

2. For many individuals, especially those at low risk to decay, the possibility of reduced numbers of and, sometimes, no

professionally administered preventive services must be considered. This possibility arises because of concerns about lack of efficiency (efficiency is defined crudely here as the impact or effectiveness in disease reduction of an intervention relative to its cost) and duplication of effort or activity. This duplication occurs when, for example, two fluoride agents that work in the same way have the same impact so that the addition of the second provides no or very little extra benefit beyond that provided by the first (see Chapter 8).

3. This preceding approach is based on the need for dental professionals to provide services that are effective (truly give reductions in disease when used under regular practice conditions) and efficient (the benefits from providing an effective service exceed their cost).

4. Although recognition of the need for this approach will grow slowly with dental professionals since it is new to dentistry, the real need for it will become more apparent as improvements in dental disease continue and societal and other agency demands for greater effectiveness and efficiency in the provision of dental services increase.

5. Because of the anticipated increasingly dentate and dentally conscious adult population in the future, there will be an overall increase in needed preventive services to adults of all ages. Thus, the long-term, overall prospects for the provision of needed preventive dental services are enhanced, not diminished, by the changing demography and epidemiology of dental disease.

6. The required preventive services in this expanded preventive market will be different (perhaps, for example, selected periodontal prophylaxes and intensive fluoride therapy to promote remineralization of coronal and root caries) and the target clientele will include a broader age range than at present. But the aggregate preventive service requirements will grow over what they are now and, with increases in the numbers of dental hygienists in many jurisdictions, the right kind of personnel to do this work will be relatively more available than in the past.

7. As the hesitant and low utilization of fissure sealants by dentists demonstrates, the uptake of even an efficacious children's preventive procedure can be a slow and complex process (See Chapter 3). It should be recognized, therefore, that to convert the future, expanded needs for prevention into demand by adults, on whom relatively little prevention has been practised in the past, it will be necessary for the attitudes of many dentists and adults towards prevention to change.

2.3 SUMMARY

1. The practice of prevention by dental professionals should be expanded but not in isolation from the many influential factors that are external to dentistry and its preventive technology.

2. Despite prevention's many tangible and intangible benefits, it must be recognized that prevention can be costly. Because of this and, especially, decreases in dental caries, the need to provide preventive services effectively and efficiently will grow in the future.

3. Because of concerns about unbeneficial duplication of preventive activities and true patient needs and cost, careful selection of the preventive procedures and the persons, and teeth and sites in these persons to receive these procedures are essential if dental practice effectiveness and efficiency are to be achieved.

4. The preventive services to be provided must be planned to minimize the oral health problems anticipated for the individual in the future in the absence of these services. Since those who will

develop little future disease require few preventive services now, targeting on high-risk persons and sites is recommended, although the technology to do this with high accuracy (high sensitivity plus specificity) is lacking at present.

5. A new, operational and epidemiologically based classification of prevention is recommended to replace or share equal billing with the traditional primary, secondary, tertiary classification. The new classification of universal, selective and indicated preventive measures considers the appropriate target group, and the provider (self or professional) and cost-benefit aspects of each measure.

6. Future changes in demography and in the burden of dental disease in the population will lead to an overall expansion in the need for preventive dental services. However, changes in the attitudes towards prevention by many dentists will be necessary as not only a shift in clientele but in the types of preventive services and most appropriate personnel to provide them are required. Patient attitudes and economic accessibility, particularly for the elderly, must also change if the need for prevention is to be converted into demand.

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CHAPTER 3

CHAPTER 3

PIT AND FISSURE SEALANTS

D.P. Kandelman and D.W. Lewis

3.1 INTRODUCTION

Pit and fissure sealants are one of the primary methods available for the prevention of dental caries. They now assume a greater relative importance in the preventive dental armamentarium since the overall decline in dental caries prevalence favours smooth more than pit and fissure surfaces.

Because of their high susceptibility to dental caries, the pit and fissure surfaces of teeth have drawn the special attention of dental clinicians and research scientists for at least 60 years. Prophylactic odontonomy as promoted by Hyatt and the painting of fissure surfaces with ammoniacal silver nitrate are two examples of this older attention (1,2). In recent years, however, emphasis has shifted to the development of adhesive resins to fill and seal deep fissured surfaces in order to change their anatomy thereby making them markedly less liable to decay.

The early, first generation sealant resins -- the cyanoacrylate and polyurethane resins -- are not now used because of their deterioration and handling difficulties, and relatively poor retention. Sustained retention and complete sealing to the enamel about the periphery of the resin to prevent microleakage are, of course, the prime requirements of a sealant. In this regard the seminal work of Buonocore who in the 1950s developed the technique of prior enamel etching with phosphoric acid to enhance sealant adhesion should be mentioned (3). Enamel etching is utilized with the most successful sealants, the methyl methacrylic resins. These incorporate bisphenol A with glicidyl methacrylate and methyl methacrylate (Bis Gma). Different Bis Gma resins are categorized according to the type of polymerization utilized -- resins polymerized by ultraviolet light, such as Nuva Seal, and self-polymerizing resins, such as Delton. A third type of Bis Gma resin that is polymerized differently is now available and will be described later.

Despite the wide ranging results in retention and caries reduction up to 1978, the Bis Gma resins generally demonstrated good adhesion to tooth surfaces for one or two years and significant occlusal surface caries reductions, with the later sealant products being superior in this regard to the earlier ones. Later in this chapter more recent evidence of the efficacy (retention and caries reductions) of the Bis Gma resins well beyond two years is provided.

Despite the complex interactions that take place during the adhesion of resins to enamel and some remaining uncertainties in knowledge about these processes, one thing is abundantly clear. And this is that the clinical application technique is critical to the success of the sealant. The required steps in applying sealants are an important later feature of this chapter.

Indications and Contraindications for Sealant Use

This obviously is an important consideration for dentists and dental hygienists in private and public dental practice who are contemplating sealant use generally and, specifically, are selecting the individual teeth to be sealed for a particular child. It is generally recognized that the morphology, eruption patterns and dental caries susceptibility of teeth should be considered. Additional specific suggestions will be made later.

Sealants are generally thought of as part of primary prevention. However, they are not contraindicated when incipient caries has occurred (4,5). Although further developments in this area are described later, previous in vivo and in vitro studies have shown that the number and metabolic activity of bacteria sealed beneath fissures were sharply reduced (5-8). However, the importance of proper sealing around the entire fissure opening, as in any sealant activity, is doubly re-emphasized in this situation.

The Simultaneous Use of Sealants and Other Preventive Measures

Since sealants have no impact on smooth surface dental caries, the combined use of sealants with systemic and/or topical fluorides and other oral hygiene and dietary preventive interventions may be important for many patients. Sealants should form one part of an overall integrated oral disease preventive program. Since cost-effectiveness must always be considered, these combined regimens that include sealants are particularly suitable and important for children who are at high risk to caries.

When combining sealant and topical fluoride applications, the topical fluoride treatment should be done after the sealant procedure has been completed. Application of the topical fluoride before the sealant treatment may interfere: i) with the quality of the process of acid etching of enamel (9); and ii) with the sealant's adhesion since a precipitate may form and be deposited in the interprismatic spaces (10,11).

When sealants are used in fluoridated communities or in combination with topical fluorides, added protection against caries is provided because fluorides' main impact is on the smooth tooth surfaces (12-15). Fissure sealants' complementary impact in reducing pit and fissure caries makes a potent preventive combination.

Other Considerations

Concern that the loss or fracture of a sealant may lead to increased caries susceptibility because the underlying "etched" (demineralized) enamel becomes exposed is not justified. Studies have revealed that this enamel quickly regains its normal appearance and resistance to solubility (16-19). Indeed, these areas previously covered with sealant are apparently more resistant to decay since resin projections remain in the enamel's interprismatic spaces (20-23). Such teeth sould be monitored closely and sealants re-applied as indicated, although there is little danger if the reapplication is delayed.

Nor is there need for concern that sealants interfere with enamel's normal post-eruptive maturation. The attachment of the sealant on the very caries resistant inclined plane areas of fissure surfaces makes the partial interruption of enamel maturation in these areas of little consequence.

Dental sealants offer a new and increasingly important approach to the prevention of dental caries. Since 1979 several highly supportive conferences (24-26) have been held. This indicates a growing interest in pit and fissure dental sealants.

The remainder of this chapter reviews, in accordance with the recent literature, six major aspects related to the sealant technique and its implementation in private practice and public health settings. These are: i) resin materials and acid etching; ii) sealant efficacy; iii) indications for sealant use; iv) the application technique; v) sealant effectiveness and adoption; and vi) efficiency issues. But first the important question of the need for sealants in view of the recent decline in dental caries is described in some detail because an understanding of the new epidemiology of the surface distribution of dental caries is a critical guide to the effective and efficient use of fissure sealants.

3.2 JUSTIFICATION FOR SEALANTS – EPIDEMIOLOGIC CONSIDERATIONS

The decline in dental caries prevalence in highly developed countries and the proportionately higher decrease in smooth surface over pit and fissure surface caries were described briefly in the introductory chapters of this publication. It is very important here to examine more particularly the data and attendant implications that this decline has for the selective utilization of fissure sealants. Since there is little appropriate Canadian data available, other probably very similar data from the United States must often be used.

Individuals and Teeth Free of Decay

As stressed in the introductory chapters, the overall decline in dental caries prevalence in Canadian children has been about 33-50 per cent during the past 15 years or so. One major characteristic of this decline is the growing number of children at each age who are now free of present or past decay experience (i.e. deft and/or DMFT=0). For example, in Ontario in 1981/82, the per cent of children free of decay on their permanent teeth for ages 7, 9, 11 and 13 years was about 77%, 50%, 33% and 22% respecively.[3] In British Columbia in 1980, just over 30 per cent of nine year-olds and 10 per cent of 13 year-olds were free of permanent tooth decay, and in the 1982 survey in the four Atlantic provinces, these figures were about 21 per cent for the 6-7 year-olds and 7 per cent for the 13-14 year-olds. Children like these who are caries free do not need fissure sealants and their greater numbers in the current period of caries decline emphasize the need for selectivity of patients in sealant application.

Changes in the type of teeth attacked by dental caries have also occurred. The low per cent of decayed permanent teeth, other than molars, was demonstrated recently by the baseline survey findings of the National Preventive Dentistry Demonstration Program (13) in the United States. At age 13, only about 12 per cent or less of the children's premolar teeth in the non-fluoridated communities and 6 per cent in the fluoridated communites were decayed (presumably on occlusal fissured surfaces). More second molars, 30-40 per cent, have already decayed at this age and, unlike the premolars, would seem to be suitable target teeth for selected sealant use. Similarly, the high caries prevalence demonstrated by the first permanent molars (58-76 per cent decayed) suggests the strong candidacy of this type of tooth for sealing since much of this decay will have occurred in the occlusal or other pit and fissure surfaces. However, even here, it is important to note that between 24-42 per cent of these first permanent molars displayed no decay at age 13 years, some seven years after their eruption. Thus, these data emphasize the need for selectivity in the teeth to be sealed.

Shifts in Decayed Surface Distribution

Based on data from the United States (27), Table 3.1 shows that proportionately less decay occurs now (16 per cent) on the smooth mesiodistal surfaces than previously (24-29 per cent). In these data, about 53 per cent of decay now occurs on occlusal surfaces which, incidentally, is similar to the 41-61 per cent occlusal surface decay found in the 1982 survey of children in the four Atlantic provinces of Canada.

It is also very important to note in Table 3.1 that, despite the increase in relative importance of "sealable" occlusal surfaces (from 49-54 per cent between 1971/74 and 1979/80), the mean number of occlusal DMFS surfaces has actually dropped from 3.5 to 2.6 DMFS due to the overall decline in dental caries during this period. (This mean reduction of 0.9 occlusal DMFS actually equals that of the proximal, mesiodistal smooth surfaces.)

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[3] Interestingly, these figures are almost identical to those of the 1979-80 National Dental Caries Prevalence Survey in the United States.

TABLE 3.1

MEAN CARIES TOOTH SURFACE PREVALENCE AND PER CENT DISTRIBUTION BY TIME PERIOD FOR CHILDREN AGES 5-17 YEARS

Surface	1935-40	HANES 1971-74	NDDP 1977-78	NDCPS 1979-80
	%	% ($\bar{x}$)	%	% ($\bar{x}$)
Occlusal	50	49 (3.5)	52	54 (2.6)
Buccolingual	21	27 (1.9)	32	30 (1.4)
Mesiodistal	29	4 (1.7)	16	1 (0.8)
		(7.1)		(4.8)

Source: Graves, R.C. and Stamm, J.W. (27).

Similarly, data from the Netherlands (28) showed that although the per cent of decayed permanent pit and fissure surfaces in seven-year-olds had increased from 85-90 per cent of the total decayed surfaces between 1969 and 1978, the absolute mean number of such surfaces per child actually declined from 2.9 to only 1.6 DMFS over this period. Thus, the popularly quoted time-related per cent shifts in decayed surface distributions are deceptive and must give way to a consideration of the absolute number of fissured surfaces attacked by decay when the selective utilization of sealants is being considered.

When assessing the epidemiologic basis for sealant use, the above "static" cross-sectional dental caries surface prevalence data are not, however, as important as the more "dynamic" surface incidence data giving the amount of new decay occurring between two points in time. The recent National Preventive Dentistry Demonstration Program in the United States, where the findings on different preventive modalities' efficacy were greatly influenced by the recent caries decline, has provided the needed kind of incidence data (29). Table 3.2 shows the surface distribution of the decay that developed over a four-year period in children initially age 6-7 and ten years living in both fluoridated (F) and non-fluoridated (NF) communities.

TABLE 3.2

FOUR-YEAR MEAN DMFS INCIDENCE BY SURFACE SITE, NPDDP CONTROL GROUP

Surface Site	Grades 1 and 2		Grade 5	
	F	NF	F	NF
Occlusal	1.32	1.73	2.04	2.61
Buccolingual	0.72	1.01	0.77	1.05
Mesiodistal (including x-rays)	0.43	1.01	1.12	2.48
Total	2.47	3.75	3.93	6.14
(Mean pit and fissure caries estimates)	(1.9)	(2.5)	(2.7)	(3.4)

Source: Tables 3.16 and 3.17, Rand Report R-3072-RWJ (29).

Occlusal decay incidence represented about 45 per cent of the total four-year DMFS increments at non-fluoridated sites and about 52 per cent at fluoridated sites. If 80 per cent of the buccolingual surfaces represent pit and fissure caries (28), the pit and fissure surface caries increments over four years are 1.9 and 2.5 DMFS for the grade 1 and 2 cohort, and 2.7 and 3.4 DMFS for the grade 5 cohort at fluoridated and non-fluoridated sites, respectively.

It is clear from Table 3.2 that the fissure surfaces represented the bulk of new decay for these children -- from 67-77 per cent of the incidence over four years in three of the groups but less than this, 55 per cent, in the non-fluoride group initially in grade 5. However, consistent with the caries decline, the mean DMFS pit and fissure surface incidence, over four years was just about two to two and one-half surfaces for the first three groups and about three and one-half surfaces for the remaining groups. This is equivalent to less than one such surface per year per child, on average, a large drop from past experience in the United States.

Summary

The decline in dental caries has resulted in a new epidemiology of dental caries distribution. Fewer children, fewer specific tooth types, and fewer numbers of pit and fissure surfaces are now targets for sealant use in regions where dental caries declines have been experienced. Consequently even though pit and fissure surface decay, preventable by sealants, has grown in relative importance in such regions, its concentration in fewer tooth types and persons increases the need for, and difficulty of selecting the most appropriate teeth and persons to receive sealants. Another way of stating this is that with the current caries decline, unless patients and teeth for sealant use are carefully chosen, the likelihood of wasteful, ineffective and inefficient sealant use is greater now than it was previously. This is the important message arising from the new epidemiology of dental caries distribution.

3.3 DEVELOPMENT OF RESIN MATERIALS AND THE ACID ETCH TECHNIQUE

As mentioned previously, cyanoacrylate and polyurethane resins are not used now because of the potential toxic effect from the deterioration of the first product and the lack of long-term retention of the second one. The greatest development in resins and composite dental filling materials resulted from the synthesis of a new monomer proposed originally by Bowen (30) and named Bis Gma. This resin constitutes the majority of the sealants and esthetic composite filling materials utilized in dental practices today. At present, Bis Gma resins are available in three major forms:

a) ultraviolet light-cured resins;
b) chemically cured or self-polymerizing resins; and
c) visible light-cured resins, the latest type of resins.

The resin may be unfilled (these are in the majority) or filled, incorporating inert particles to improve abrasion resistance, although Jensen and co-workers found recently that filled sealants do not demonstrate greater occlusal wear than unfilled (31). Commercially available sealants are transparent, tinted or opaque. Methyl benzoic ether initiates polymerization in the presence of ultraviolet or visible light.

Enamel etching is a critical step which precedes the sealant application (3). Most of the commercial sealants presently use phosphoric acid for etching, at concentrations ranging between 37-50 per cent. Although the concentration of phosphoric acid influences the degree of morphologic changes in etched enamel (32), the superiority of one concentration over another has not been demonstrated in clinical investigations.

The effect of different etching periods on the bonding strength has been investigated in vitro (33-35). Williams and Von Fraunhofer (33) reported that a 20 second etch and 20 second washing period would save chairside time without significant loss of adhesion as compared to the recommended 60 second etching time. These results were recently confirmed in a clinical study by Stephen and others (36). Nevertheless, acid conditioning has been carried out for one minute in most of the published studies.

3.4 EFFICACY OF SEALANTS

Efficacy concerns how well an agent or procedure works under the ideal conditions usually found in a randomized clinical trial.

Numerous randomized clinical trials have demonstrated the efficacy of Bis Gma resins. Sealant efficacy is assessed both on retention and caries reduction; these two characteristics are strongly associated as shown recently by Rock (37). Several excellent review articles (38-40) have described high rates of caries inhibition and sealant retention particularly in the two-year results, but also after 5-7 years as shown in Table 3.3 (22, 41-46).

Sealant retention can now be compared with the longevity of other conventional restorations (40), but sealant efficacy, nevertheless, decreases with time. Consequently, sealant usage should not be considered as a once-only treatment without further examination or reapplication being required.

As seen in Table 3.3 the self-cured resins have superior clinical performance (retention) over the ultraviolet initiated ones (39,40).

The newer visible light-cured sealants appear very promising. In one-year studies, Sven and Jensen (47) reported 94 per cent retention and Rock and Evans (48), 75 per cent. In each case the retention was almost identical to that of chemically cured resins, although after three years Rock and Evans (49) found retention of the chemically cured resin higher than the visible light-cured one (56 per cent vs. 43 per cent). These results will have to be confirmed by further long-term investigations to see if the initial promise is fully justified.

TABLE 3.3

EFFICACY OF FISSURE SEALANTS IN CLINICAL TRIALS LASTING FIVE YEARS OR MORE

Investigator(s) (Year; Ref. No.)	Polymerization Type*	Length of Study (Yrs.)	Initial age of Subjects (yrs)	Type of Permanent Teeth	Per cent Retention (Fully Sealed) %	Per cent Occlusal Caries Reduction %
1. Richardson et al. (1981, 41)	UV	5	6-20	Prem, 1st, 2nd M	19	58
2. Gibson et al. (1982, 42)	Chem	5		1st molars	67	51
3. Horowitz et al. (1977, 22)	UV	5	5-8	Prem, 1st, 2nd M	42	37
4. Meurman et al. (1983, 43)	UV	5	7 (avg.)	1st molars	72	60
5. Houpt and Shey (1983, 44)	Chem	6	6-10	1st molars	58	56
6. Mertz-Fairhurst et al. (1982, 45)	Chem UV	6	6-7 (most)	1st molars	68 37	55 8
7. Mertz-Fairhurst et al. (1984, 46)	Chem UV	7	6-7 (most)	1st molars	66 31	55 12

* UV = ultraviolet light polymerization
Chem = chemical polymerization, i.e. self-cured resins

3.5 INDICATIONS FOR FISSURE SEALANT USE

As demonstrated in Section 3.2, the need for a greater selectivity of the specific patients and teeth to receive sealants has increased as a result of the decline in caries in developed countries.

The procedure is maximized when sealants are placed on those teeth that, otherwise, would certainly have decayed. This is the ideal criterion for targeting sealants. The general criteria of selection rely on tooth and patient caries susceptibility, age, oral hygiene status and the individual's past caries experience; that is, estimates of future caries susceptibility. At present, no explicit foolproof ideal criteria exist for selecting individuals or teeth requiring sealants.

Resin may be used for selected permanent molars and, possibly, premolars, as well as deciduous molars. In particular, the anatomy of the occlusal and lingual fissure surfaces of upper molars, occlusal and buccal pit surfaces of lower molars (50,51) and cinguli of the upper anterior teeth should be carefully examined. Treatment should be restricted to those teeth having deep, narrow fissures or pits in which one can catch the tip of an explorer. The temptation to say "sticky" fissures must be tempered somewhat by the 1985 findings of Gibson and Richardson in British Columbia that nearly 20 per cent of the control teeth with sticky fissures in their sealant study did not worsen after 30 months (52).

Because of their known predisposition to caries, newly erupted first and second permanent molars with the foregoing morphology should have priority in selection, taking into consideration the prevalence of proximal caries. Despite their better sealant retention, premolars, for reasons discussed previously, now have less priority than permanent molars as candidates for sealant application.

Consistent with the eruption time of the first two permanent molar teeth, fissure sealant placement should be targeted at two major age groups: 6-8 and 12-14 year-old children (53). Sealants are not indicated for teeth that have remained caries-free for three or four years or when there is already proximal caries.

Burt (54) in a report prepared for the Council on Dental Research of the American Dental Association having particular emphasis on sealants and prepaid dental care recently suggested standards similar to those presented here. These included:

a) the sealing of fissures only in permanent molars and within four years of their eruption (by age ten for first and age 15 for second molars);

b) non-reimbursement for sealing premolars and primary molars; and

c) limitations of sealed teeth to those free of proximal caries and without previous restorations on the surface to be sealed.

The state-of-the-art on indications for sealant use consists of recommendations, and perhaps even consensus, about which teeth in the majority of children should not be sealed. However, what remains to be revealed through research is the accurate identification of the susceptible fissure surfaces in permanent molars requiring fissure sealants for primary dental caries prevention.

As mentioned earlier many pits and fissures remain caries-free, particularly in populations with a low caries incidence. The National Preventive Dentistry Demonstration Program (13) showed that 20 per cent of the children accounted for nearly 60 per cent of all decay found. Thus, in public settings, it is advisable to select only high-risk groups for whom, given that sufficient smooth surface caries is expected to justify it, a fluoride and combined sealant program could be established. Similarly, in private practice, sealants should be emphasized mainly for high-risk children.

In addition to those cited earlier in this chapter, a number of recent studies (55-61) have shown that there was no risk involved in applying resin to teeth with incipient caries.

In this regard it should be recognized that the report of the National Institute of Health (NIH) Consensus Development Conference (26) stated that "children may benefit from having small carious lesions sealed". Researchers at the Eastman Dental Center in Rochester have used sealants in this manner for over ten years and found it to be safe and effective, and more cost-effective than the traditional sealing of sound pit and fissure surfaces (61). Nevertheless, further clinical studies should be conducted to determine the utility of this approach on a broad basis of experience. Where applicable, dentists might consider informing patients, or their parents, about the possibility of using this approach and thus give them the opportunity to make a choice.

Despite the attractive possibilities arising from sealing certain carious lesions and the associated cost-effectiveness potential, it should be emphasized that the sealant procedure was developed and is currently used and promoted more as a primary preventive technique than as a therapeutic one.

3.6 APPLICATION TECHNIQUE

While the technique for applying the resin coating is easy, certain precautions must be observed to ensure sealant retention. The application technique consists of three main steps:

1. pretreatment of the enamel;
2. application of the resin; and
3. quality control examination of the sealing operation.

Pretreatment of the Enamel

It is important to clean thoroughly the area where the resin is to be applied, using an abrasive paste and a rubber cup or a brush or air polishing device. The removal of debris and calcified dental plaque enhances the action of the phosphoric acid solution (62,63). This abrasive paste should not contain glycerine or fluoride, although it has not been clearly demonstrated that a fluoride paste could interfere with the action of phosphoric acid solution.

Air polishing devices can also be effectively used for the prophylaxis of the surfaces which have to be sealed. Gwinnett (64) suggested that they could remove significantly more soft deposits than a brush or a rubber cup and that the spray of water and sodium bicarbonate does not subsequently affect the quality of the acid conditioning. The use of these devices is particularly interesting in occlusal surfaces of children's teeth because deposits are not yet calcified in the deep dental fissures.

Following prophylaxis, the area should be rinsed to remove the paste and dislodge microparticles. Next, the teeth to be treated should be isolated and dried.

Use of rubber dam is certainly the best way to maintain adequate and dry operative field conditions but it cannot always be used, particularly for sealing newly erupted molars. Cotton rolls have been used to isolate the teeth to be treated in most of the studies. Eidelman and others (65) in comparing the retention of self-cured sealants applied using rubber dam or isolation by cotton rolls, reported that the results were not significantly affected by the method of isolation. Similarly neutral findings about the absolute necessity of rubber dam have been reported when sealing primary molars (66) and when dental students applied both chemical and ultraviolet light-initiated sealants (67).

Subsequent to isolation and drying, phosphoric acid should be applied specifically to the inclined planes of the cusps wth a cotton swab, a brush or a sponge. This conditioning agent is available as a gel or solution. The solution should be applied to the cuspal planes for 60 seconds; the gel is left on these tooth surfaces for the same period of time.

Following this, the operative field should be thoroughly rinsed with water for 10-15 seconds, or for 30 seconds if gels are used (62). Then the teeth should be carefully dried using compressed air (35).

Examination of the entire conditioned enamel surface should now show a dull finish devoid of any trace of moisture.

The cotton rolls should be replaced with new ones prior to placement of the sealant.

Several studies (63-65) have reported that salivary contamination at this step could affect the bonding, and subsequently cause sealant failure, due to the rapid deposit of an organic pellicle in the micropores of the etched enamel surfaces. Consequently, if contamination occurs at this stage, repetition of the etching phase is highly recommended. A ten second reapplication has been suggested by Hormati et al.(71), while Silverstone proposed the repetition of the entire phase to assure optimal bond strength (72).

The bond between the etched enamel and sealant is very sensitive to surface contamination, and etching, washing and drying times. Although some laboratory and clinical study findings have suggested variations in each of these steps may be possible, Ripa (38) believes that there is insufficient evidence at the present time to change the recommended procedure which is a pumice prophylaxis, acid etching for 60 seconds and a minimum wash of ten seconds.

Application of the Resin

The technique depends on the type of resin selected and it is therefore important to follow closely the manufacturer's instructions. The sealant is applied with a fine brush or a specially designed syringe. The self-cured resins, due to their low viscosity, flow readily over the occlusal surface and particularly into the pits and fissures.

It has been suggested that the resin "Nuva Seal" (an ultraviolet-initiated sealant) be brushed into the etched surface to produce well-formed tags (73). However, it does not need to be painted vigorously with the brush, since this could trap air bubbles and lead to reduced adhesion.

The major advantage of the visible or ultraviolet light-activated systems is the opportunity to control polymerization. With self-cured resins, the hardening of the resin takes place at a fixed time after the addition of the catalyst. Thus, self-cured resins must be placed rapidly in order to allow tag formation before the sealant sets. However, with light-cured systems, the operator has as much time as needed for application of the resin before initiating polymerization by means of the light source.

Quality Assessment of the Sealant Procedure

Following the application, it is recommended that the surface of the resin be examined with an explorer to determine whether retention is adequate. If the coating can be easily detached, the whole procedure must be repeated.

Finally, it is essential that resin thickness be checked and premature contacts be corrected if necessary. This is particularly important if semi-filled resins are used, as they are intended to be more abrasive resistant.

3.7 EFFECTIVENESS AND SEALANT ADOPTION

Effectiveness concerns the appropriate and widespread use in real-life practice of a procedure that has been shown in the ideal circumstances of a clinical trial to be efficacious. Proper application technique and wide but selective use of sealants by dental practitioners are important factors in achieving effectiveness.

Broad adoption of sealants has not yet occurred, despite the facts that this preventive measure was developed about 20 years ago, and has been commercially available, successfully tested in numerous studies, and reasonably well advertised by manufacturers.

Several researchers (74-77) have evaluated the reasons for the slow acceptance of sealants. In 1975, Gift et al.(74) reported the attitudes of dentists in the United States toward the use of the sealants. They showed that dentists were poorly informed about the properties and the technology of sealants, and were not yet convinced of the effectiveness of sealant use in preventing caries. About ten years later, dentists' views showed little improvement according to a survey of the American Dental Association Health Foundation (78). Various factors were reported during the NIH conference on dental sealants (26) as contributing to the under-utilization of sealants by dental professionals.

These factors are listed as:

a) perceived lack of data demonstrating efficacy;

b) possibility of sealing in decay with subsequent lesion progression;

c) lack of retention of sealants;

d) unfamiliarity with technique;

e) difficulty in explaining the rationale and procedure to patients and parents;

f) lack of third-party sealant coverage;

g) belief that amalgam restoration is better and more economical;

h) insufficient instruction in curricula for dental personnel;

i) restrictive state dental practice acts; and

j) deficiencies in public awareness about sealing and its benefits.

A vigorous combined effort from dental educators, dental practitioners, manufacturers, government agencies and health insurers is required to promote the greater use of sealants and overcome these professional, economic and technology-related impediments to sealant use.

In dental offices this preventive measure, like any other, should be incorporated into daily practice. It does not require any special organization and should become an integral part of a preventive program similar to the use of topical fluorides and instruction in the principles of oral hygiene and nutrition.

In dental practice, children may be seen every six or 12 months; it is then opportune to examine the treated teeth for the success of the resin bonding. The first six-month verification of sealant retention is thought to be the most important because if the material is to be lost, this usually occurs shortly after the original application. Re-application of missing or defective sealant at this recall appointment is appropriate. However, it must be emphasized that there is no evidence that missing or defective sealants increase the likelihood of caries development.

Should this procedure be performed by dentists or other dental health personnel? The answer is both -- if patient and tooth selectivity and the proper technique are used! The Council on Dental Materials and Devices of the American Dental Association (79) indicated back in 1974 that sealing agents may be applied under the supervision of the dentist by dental personnel who have received the appropriate educational preparation. However, in the United States, only about 30 of the 50 states now allow dental assistants and/or dental hygienists to apply sealants (76). In Canada, all jurisdictions except Alberta and the Yukon and Northwest Territories allow dental hygienists to apply sealants. (In Quebec, sealant applications by dental hygienists are allowed only for children). It is noteworthy that the public dental programs of some provinces such as Saskatchewan have recently adopted the wide use of dental sealants applied by dental health personnel other than dentists (53). The delegation of this procedure is supported by a number of clinical studies (80-84) that were undertaken in the mid 1970s.

Other dental health personnel who have received the appropriate educational preparation are ideally suited to employ this preventive measure. Their greater involvement would enhance sealant adoption and the community-wide effectiveness of sealants. Thus, dentists are encouraged to delegate fissure sealing. Just as they are for the other preventive activities in the dental office, dentists also are generally responsible for the supervision of this preventive treatment. As demonstrated above in regard to dental hygienists, the inequities in Canada in the personnel other than the dentist who are allowed to apply sealants are curious and difficult to understand. These inequities should be removed.

The use of sealants in a public health program is even more complex since it raises additional organizational and administrative problems (51). For instance, it is difficult to determine the optimum frequency of sealant program activity since the eruption of teeth and the degree of susceptibility to caries varies with each individual in a group. Moreover, good caries predictors for selecting high-risk individuals and teeth to enhance sealant cost-effectiveness are unavailable. As well, considerable time and personnel resources are needed, for example, to follow up treated children on a regular basis and to return to previously treated classes to find those children with newly erupted permanent molar teeth. Costs may be substantially cut, however, if appropriately trained dental personnel, other than dentists, take over the application of the resin, using portable equipment. This equipment must include whatever is necessary to ensure complete dryness of the operative field.

Even though some of the experiments conducted in public health programs have given equivocal results (85-88), large school-based sealant programs have been implemented in Kentucky, Minnesota and New Mexico in the United States (75), and in the province of Saskatchewan in Canada (53), among others. These programs are very well accepted and appear to be financially feasible.

3.8 EFFICIENCY OF SEALANTS

Efficiency concerns the optimal use of resources to achieve stated goals using agents or procedures previously proven to be effective (89). The use of sealants has raised important questions about cost-effectiveness; however, sealant cost-effectiveness analyses to date have not been conclusive. This is not surprising since difficult conceptual and methodological problems have been identified in cost-effectiveness studies in dentistry generally and with sealants specifically (54, 90-92). A brief review of some of these difficulties in respect to sealants follows.

The necessity to use data arising from clinical trials utilizing meticulous application techniques, sometimes specially selected teeth and patients, the inefficient half-mouth study design and less than real world costs have caused problems for the economic analysis of sealants relative to their use in regular practice circumstances. These are some of the reasons that make the derivation of sealant effectiveness which is an essential precursor to the determination of efficiency (89), difficult.

Similarly, data arising from clinical studies in which sealants are routinely, rather than selectively applied enhance findings of economic inefficiency since each sealed tooth that otherwise would not decay requires the same resources as the tooth that would. Despite this need to focus attention on high-risk individuals in both private and public practice to achieve efficiency in sealant utilization, the current state-of-the-art does not permit precise identification of these high-risk target individuals. Further research is urgently required to obtain a simple and cheap diagnostic test in order to solve this important issue. Some inroads in this area, such as the determination of relative caries experience or the use of caries activity tests, have already been suggested (93-95).

The complementary tooth surface preventive action of sealants and fluorides understandably has led to the suggestion that greater efficiency of sealant use could be obtained by combining these with other preventives at one patient sitting (96). However, the only available data suggesting complementary benefits from this particular combination do not separate out the individual treatment effects of each procedure nor assess their costs (87, 97-99).

Technological considerations include equipment costs and the use of dental personnel other than the dentist. Currently, self-cured resins which have higher retention and lower equipment costs than ultraviolet light-cured resins appear to be more economical for use in public health. In private practice the visible light-cured resins appear to be very promising as they have shown comparable short-term retention and, like the ultraviolet light-cured resins, require a light that may also be used for composite restorative procedures. Greater sealant efficiency will result if cost savings due to the use of other dental personnel in sealant applications (38,100) are passed on to patients, payer agencies and program budgets.

Current sealant cost data do not permit reliable estimates. In the United States, wide variations in costs are evident ranging between $1.20 per tooth and $36.41 per child in public programs as reported by Burt (92), and fees between $5 and $25 (mode of $10) per tooth and $10 and $60 (mode of $20) per single quadrant in private practice as reported by Ripa (38). Difficulties in the assessment of costs are related to the influence of many different factors such as caries susceptibility, tooth morphology, equipment and the way of accounting for labour, materials and capital costs.

There is an urgent need for further research into the economics of sealants that will give reliable cost-effectiveness estimates both for this procedure alone and when it is combined with other preventive measures.

3.9 CONCLUSIONS, RECOMMENDATIONS AND RESEARCH NEEDS

The use of sealants is feasible in both private practice and public health programs, although the organizational difficulties differ for each practice mode and the cost-effectiveness aspects need clarification. Careful selection of the children and teeth to be sealed and strict adherence to the application routine in which the maintenance of a dry field is especially critical, make the use of pit and fissure sealants a valuable, rewarding and effective preventive measure.

Recommendations

1. The dental caries decline increases the need for careful patient and tooth selection if sealants are to be provided in an effective and efficient manner.
    a) Newly erupted permanent molar teeth having deep, narrow pits and fissures in high caries risk children are the main target teeth for sealant placement.
    b) Molar teeth with proximal caries and teeth that have been caries-free for three to four years after eruption should not be sealed.
    c) The two major target age groups for sealing are children 6-8 years old for the first permanent molars and 12-14 years old for the second permanent molars.
2. For high sealant retention, each step in the recommendations for sealant application, especially the maintenance of a dry field, must be followed rigorously. Unless further research proves otherwise, the recommended technique includes a pumice prophylaxis, acid etching for 60 seconds and a minimum ten-second wash.
3. Dental hygienists, dental therapists and dental assistants who have received the appropriate educational preparation are ideal for sealant applications; their increased involvement in sealing should be encouraged since it may help to improve the adoption, effectiveness and efficiency of pit and fissure sealants. Legislation allowing the application of dental sealants by dental hygienists should be similar in all Canadian jurisdictions.
4. Sealant use should be integrated into a total oral disease preventive program in both private and public health dental practices. Since children ordinarily are not severely affected by periodontal disease and since smooth surface dental caries in many

children is now greatly diminished, the highly selective use of sealants often will be the key component of this program. It should not be ignored.

5. Dental educators, dental professionals, dental public health officials and manufacturers should individually and collectively work to promote greater use of dental sealants and to convince private and public dental insurers that the selective use of carefully applied sealants is an important and effective measure for high caries risk children.

Areas for Further Research

A number of research needs have been identified in this review. They are summarized below and categorized by the indicated topic heading.

Sealant technique

Further studies are needed into the best combination of etching, washing and drying times to achieve optimum sealant bonding and efficiency, and into the prior prophylaxis, including the use of air polishing devices.

Clinical studies

Further clinical trials into the long-term effects of sealing with the visible light-cured resins and comparative community trials using various sealants under regular practice conditions are required.

Studies of the contributions and relative cost of each component when other preventives such as fluorides are combined with sealants would be helpful.

Sealant indications

Improved methods of predicting high caries risk to provide more accurate guidelines for selecting teeth and patients for sealant placement are very desirable.

Further comparative clinical trials are needed to assess the therapeutic use of sealants for the early treatment of carious lesions.

Economic studies

Improved cost-effectiveness methods are required for dentistry generally and sealants particularly, including consideration of sealants in fluoridated and unfluoridated regions, in combination with other preventives, in deciduous teeth, and when other dental personnel and different risk groups are used.

Behavioural research

Further studies of sealant diffusion into various forms of dental practice and of sealant promotion methods are needed.

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CHAPTER 4

CHAPTER 4

PLAQUE CONTROL

D.L. Anderson and D.W. Lewis

Bacterial plaque is essential to the development of dental caries, gingivitis and periodontal diseases. Thus various individually- and professionally applied methods of supragingival plaque removal have been studied, promoted and practised to prevent or control dental disease. As early as 1938, Bodecker had predicted that new therapeutic procedures could effectively protect dental tissues from bacterial aggression. This observation is still valid, and good oral hygiene continues as a primary preventive goal.

4.1 NEW EPIDEMIOLOGIC AND PLAQUE CONSIDERATIONS

Before reviewing recent developments on plaque control, some newly recognized facts and considerations about bacterial plaque and the epidemiology of periodontal disease are highly pertinent (1,2).

1. The prevalence and severity of periodontal attachment loss appears to be considerably lower in adults residing in developed countries than was believed previously (3-13).

2. Periodontal disease is now known to be very site-specific, episodic and difficult to predict. Some sites that seem, on the basis of their characteristics, to be very liable to further early destruction are surprisingly quiescent for variable periods of time, whereas others that do not seem to be likely candidates unexpectedly display disease and attachment loss. The majority of sites exhibiting loss are concentrated in a small proportion of people (1,2).

3. The main aim of plaque removal is to improve dental health; thus, disease and not plaque criteria are the ultimate measures against which plaque removal should be evaluated.

4. All dental plaques are not necessarily harmful (14-19). The presence of nonpathogenic plaque may retard the establishment of pathogenic microorganisms (20,21).

5. The presence of some plaque and some calculus, although related to gingivitis, has been shown to be compatible with minimal attachment loss (22-24) and the retention of a functional dentition through to old age.

6. Although minimal acceptable plaque levels and optimal composition are presently unknown, the goal of any plaque control program should at least be a level of plaque that is consistent with the retention of a functional dentition throughout life.

7. It is now recognized that the qualitative differences in the bacterial flora of the plaque relate more to its pathogenic potential than do the quantitative mass or area of the plaque.

Although these very recent findings do not diminish the preventive importance of plaque control, they do better define the nature of its goals and better establish the appropriate contextual framework in which supragingival plaque control should be evaluated.

4.2 INDIVIDUAL MECHANICAL MEASURES

Toothbrushes, Brushing Methods and Frequency

Toothbrushing is the most widely practised oral hygiene procedure in the industrialized countries. Nearly all own a toothbrush (99-100 per cent) and brush their teeth (95-98 per cent) (25). From a professional dental perspective, toothbrushing is performed for three basic purposes -- to remove potentially harmful supragingival bacterial plaque from facial and lingual tooth surfaces, to act as a vehicle carrying fluoride to tooth surfaces, and to help remove stain from teeth (26). From a public perspective some of the reasons cited for toothbrushing are cosmetic, and to achieve oral cleanliness and to prevent decay and to a much lesser extent, gingival disease.

Little conclusive research has been undertaken in recent years on the best design and type of toothbrush (27,28) and bristles (29,30) required to remove plaque. This lack of research apparently is an accurate reflection of the belief that the toothbrush's characteristics are less important than the characteristics, motivation, diligence and dexterity of the users. Perhaps for the same reasons, recent studies comparing the efficacy of various toothbrushing methods on supragingival plaque removal have been similarly infrequent (28, 30-33) and inconclusive, although the roll method has been further confirmed as less effective than others in plaque removal. The frequency of toothbrushing to remove plaque is less important than the effectiveness with which brushing is performed. Since 1979 there has been no new research demonstrating the need for a particular frequency of toothbrushing. Duration of toothbrushing was found to be approximately one minute and for some young adults just over half a minute (34-37).

There has been no definitive recent research comparing manual and electric toothbrushes that shows the superiority of one over the other, although preliminary results with an electric brush having counter-rotating tufts are promising (38-40).

Reports of tissue damage related to toothbrushes and toothbrushing have, however, appeared in the recent literature. These gingival lesions range in severity from acute to chronic (41-45) and are related both to the design characteristics of brushes (bristle stiffness and shape of bristle ends) and the frequency, duration and way of brushing (42, 45-48). It is speculated that these lesions may increase as awareness about oral hygiene grows (26).

Although public performance may belie this, toothbrushing using currently available brushes and methods is capable of removing supragingival plaque from facial and lingual tooth surfaces and of preventing gingivitis in these areas. However, there is no good evidence that toothbrushing per se at any frequency reduces dental caries; this, of course, does not refer to the well-established reduced caries incidence rendered by the use of a fluoride dentifrice.

In view of the paucity of recent research in this area, the earlier findings on toothbrushing, with only slight modification, are still appropriate. These follow:

1. At present, there is no scientific basis for a recommendation regarding the ideal number of toothbrushings per day. Until such evidence becomes available, it seems reasonable to suggest:

    i) brushing once a day for subjects who have low susceptibility to dental caries, sound gingival tissue and the ability to brush carefully;

    ii) brushing after meals or at least twice daily if done correctly using a low abrasion toothpaste for adults with periodontal problems, for adults very susceptible to dental caries, and for children and adolescents.

2. It is not possible at this time to delineate the superiority of any one toothbrush or toothbrushing method over

another. Motivation and dexterity in toothbrushing are as important as the method used.

3. For this latter reason, electric brushes may still be recommended for such patients as:

   i) the handicapped;

   ii) certain young children who are unable to use a manual brush;

   iii) adults who lack manual dexterity.

4. The recommended characteristics for a manual brush are:

   i) soft nylon bristles of 0.2mm diameter and 10mm long, with rounded polished ends;

   ii) a small brush head (10mm x 30mm), multitufted and straight trimmed;

   iii) a straight handle, semi-rigid, wide and long.

Dentifrices

As an aid to dental health, dentifrices have had a long history; over several hundred years, products have appeared containing various materials including herbs, honey, minerals and even sulphuric acid. Serious research into dentifrices commenced in the present century when toothpaste abrasives and therapeutic agents became the object of scientific investigation.

Young adults clean their teeth more for cosmetic and social reasons than for health purposes. By contrast, parents generally choose for their children a fluoride dentifrice, which has a therapeutic function. The line between cosmetic and therapeutic functions is not easily drawn. Most modern dentifrices would satisfy several of the following objectives:

- cleaning of teeth;
- polishing of teeth;
- providing a pleasant sensation and odour to the oral cavity;
- applying fluoride to tooth structure;
- eliminating pain from certain sensitive areas of the teeth;
- reducing deposition of supragingival calculus.

In 1979 the following recommendations about dentifrices were reached:

1. As also observed in the fluoride chapter, the use of toothpaste containing fluoride provides a definite, though modest, reduction in susceptibility to dental caries.

2. The use of dentifrice also benefits dental and gingival health in that it encourages toothbrushing and increases the efficiency of plaque removal.

3. The use of dentifrice in conjunction with toothbrushing is recommended to prevent the build-up of brown pigmented pellicle on the teeth. For most people, currently available dentifrices are sufficiently abrasive for this purpose.

4. The routine use of highly abrasive tooth powders or toothpastes should be discouraged since this can lead to rapid abrasion of tooth tissue in which root surfaces are exposed.

There has been little recent research on this topic. However, two newer studies have shown that the rate of plaque regrowth is slower when a dentifrice, rather than water only, is used (31,49).

Frandsen (26) in 1985 noted the increased concern today about the clinical problem of cervical abrasion which may in the future become even greater as the longevity of dentitions is extended. He also noted the lack of research into the relative contribution of toothbrush, toothbrushing and dentifrice to abrasivity. This need for more research into abrasivity is not new. There has, however, been continuing review and clinical research on hypersensitivity (50-53).

Very recently, two new anticalculus dentifrices containing soluble pyrophosphate and sodium fluoride have been marketed. Clinical trials and laboratory studies suggest that these two products significantly reduce the occurrence and severity of new calculus formation (54-57) and dental caries (58). Regarding this development several points should be made. With particular relevance to the topic of this chapter, it should be recognized that dental plaque and not calculus is the primary etiologic agent in periodontal disease (59). It is also noted that the effect of these dentifrices on calculus and, in fairness, marketing claims about them are that they are cosmetic since they only reduce the formation of new supragingival calculus; they do not have, or claim to have, a therapeutic effect on gingivitis and other periodontal diseases nor extant supragingival and subgingival calculus. Although shown to be efficacious in short clinical studies (two to six months in duration for calculus and one year for caries) using selected calculus-formers and Taiwanese children with high dental caries (54-58), further long-term clinical studies of the effectiveness (including enamel remineralization) of these products on the general population are warranted. Since these products affect the visible build-up of "unsightly" calculus, their long-term impact on dental utilization and demand for professional prophylaxes (as defined in Section 4.3) is also of interest.

Interdental Cleaning

Except for anterior teeth having normal papillae, toothbrushing even when properly done, cannot clean plaque from proximal tooth surfaces. Thus, interdental cleaning represents an integral part of good oral hygiene practice.

Dental flossing is a major interdental cleaning method. This procedure is even more technique-sensitive than toothbrushing and tissue damage due to improper flossing is quite possible. Because of the need for proper technique, the standard method for flossing is quoted below. This is followed by some information on recent flossing studies, including ones which suggest a need for great caution in flossing between teeth having normal interdental papillae, and ones which indicate that there is little difference between waxed, unwaxed and variable diameter floss.

There is only one well-described technique of flossing recommended for adults (60-63). This technique is much more difficult to teach and learn than brushing methods and some precautions are required:

i) the interdental contact point should be passed with care;

ii) the floss should be slipped gently into the gingival crevice and should go around the proximal surface of the tooth;

iii) the up and down vertical motion should be combined with sufficient lateral pressure to keep the floss in continuous contact with the surface of the tooth;

iv) a fulcrum with upper arms or extra-oral hand/finger rests should be established.

The 1979 conclusions about flossing follow. It should be noted that concern exists about the correct age, 8-10 years in conclusion number two, for children to begin self-flossing. It has been suggested that age 12 years would be more appropriate. Although some research in the early 1970s indicated that children 8-10 years could demonstrate effective self-flossing after ten to five practice sessions, respectively, more up-to-date research to answer this question is needed.

1. It is recommended that dental floss be used at least once a day, when brushing; daily use thus completes the cleansing of all tooth surfaces.

2. Dental floss is essential for the daily cleansing of the proximal surfaces of the

teeth. Parents should floss the teeth of children between three and eight years old. Children 8-10 should be taught and practise the use of floss in school. This hygiene technique requires frequent monitoring, since coordination and precision of movement have an effect on the final result. (See further discussion below).

3. Learning the technique can be made simpler if children use the floss in a loop, 10-12 centimeters in diamater (63), which can also be recommended for adults with handicaps and limited coordination. (See further discussion below).

4. Unwaxed floss is recommended for people with normal interdental contacts; waxed floss may be preferred if faulty restorations are apt to fray the floss or with very tight contacts. (See further discussion below).

5. The choice of floss diameter depends on the morphology of the interdental spaces, but the thickness recommended by Bass (267 micrometers) is suitable in most cases. (See further discussion below).

A number of investigations utilizing floss have been published in recent years. In one of these (64), self-flossing by children did not give reductions in the incidence of proximal surface caries. This contrasted with the results of Wright et al.(65) who found, with young children, a reduction of about 50 per cent in caries in the proximal surfaces of their teeth which had been flossed daily in school by dental assistants.

Other studies have demonstrated no difference in plaque removal and/or gingival health when waxed or unwaxed floss (66-68) or variable diameter floss (69,70) were used. Although these findings do not vitiate the above conclusions numbers four and five, they do underscore the uncertaintly that prevails and the need for more research.

Incorrect technique may cause damage to the gingival papillae and abrasion of the proximal surfaces of teeth (71,72). A recent study (73) does impinge somewhat more strongly upon recommendation two above, and perhaps also number three, inasmuch as it showed that the flossing of healthy interdental papillae in children resulted in a tearing of the junctional epithelium. Since the junction epithelium was re-established within two weeks, the safety of flossing daily below the gingival margin in children was confirmed according to the study's author (73). Frandsen (26), however, has questioned whether this study of one flossing action and the subsequent repair within two weeks, should be generalized to the point of justifying daily flossing of children's healthy interproximal gingivae.

In other recent studies, proximal supragingival plaque removal by floss was compared to that of toothpicks (74,75) and interdental brushes (76-78). The results were equivocal. The floss and toothpicks with a handle permitting a lingual as well as a buccal approach, and interdental brushes, were found to be equally efficacious in two studies (75-78), whereas the floss was better than toothpicks without a handle permitting a lingual approach, in another (74). With reduced papillae, the interdental brush was superior (76,77).

Oral Irrigation

Very little research on oral irrigation and plaque removal is being published. No research on the impact of forced irrigation on dental caries incidence was found. Hence the previous recommendations are only slightly modified as follows:

Oral irrigators cannot be recommended as a primary means of plaque removal, for when used alone neither plaque nor gingival inflammation is controlled. Irrigators can play a supportive role in the removal of debris and plaque loosened by other means. In the future irrigators may become useful in the delivery of therapeutic agents (79,80).

Plaque Control Programs

Plaque control programs have been developed on the hypothesis that there is a close relationship between oral hygiene and dental health and between bacterial plaque and dental diseases. Plaque removal by mechanical means such as brushing and flossing has, therefore, become an important objective of many preventive dental programs.

Few large scale, school-based, plaque control programs have recently been conducted and evaluated. And those that have, have not been conclusive (81-84). Thus, the following slightly altered 1979 finding about such programs still applies:

Plaque control programs alone do not lead to sustained or clinically practical reductions in plaque formation in the majority of people, nor can they reduce significantly the incidence of dental caries. These programs must be combined with other preventive procedures, such as fluorides, in order to be effective (85).

4.3 PROFESSIONAL MECHANICAL MEASURES

Prophylaxis

As used in this chapter, dental prophylaxis -- a term which unfortunately has a wide variety of meanings -- consists of scaling, root planning, and polishing to achieve:

1. removal of all supragingival and subgingival plaque, calculus, deposits and overhangs of restorations;
2. removal of extrinsic stains and polishing of all tooth and restored surfaces; and
3. cleaning of appliances.

Based on a combination of recent research and the 1979 findings, a number of conclusions about the value and frequency of dental prophylaxis can be made:

1. Professional tooth cleaning every two weeks in conjunction with intensive personal oral hygiene, has been shown to be effective in prevention of dental caries, gingivitis and periodontitis in experimental settings, but this is a costly procedure which cannot be recommended for general use, or even selected use, at present.
2. For children, the annual or semi-annual dental prophylaxis, by itself, does not have therapeutic value against caries or gingivitis. It occasionally is required for children who rapidly accumulate stain, and can be an introductory procedure to help encourage regular dental visits.
3. Several recent studies have shown that routine polishing prior to topical fluoride application provides no additional benefit (86-89).
4. For adults, the annual or semi-annual dental prophylaxis, by itself, is not a preventive measure against caries. For adults without periodontal disease, prophylaxis in which calculus is removed periodically according to its rate of accumulation in each individual is recommended. For many young adults, only an annual prophylaxis is needed.
5. In patients who have had periodontitis, disruption and removal of subgingival plaque and calculus at three-month intervals may prevent recurrence of disease (90-99). In disease-free areas, instrumentation and polishing should be limited to removal of plaque and obvious stain.

Although further research to clarify the situation is needed, the latter admonition about limiting the instrumentation in disease-free areas arises from the findings of clinical trials in patients with periodontitis which showed that scaling and root planing or surgical procedures in sites with shallow pockets resulted in loss of attachment. Since other studies have indicated that patients are generally unable to remove plaque sufficiently to prevent caries and loss of periodontium, it may be important for therapists to remove subgingival plaque from disease-free areas to keep them disease-free, even though scaling and planing of the root surfaces in these areas may be contraindicated.

Restorative Dentistry

Several factors associated with restorative dentistry have been identified as predisposing to the accumulation of plaque and subsequent periodontal disease, especially gingivitis. These factors include crown contour, marginal fit and location. Although the evidence is not overwhelming, the avoidance of over-contouring, deficient or overhanging margins (100-103), and subgingival placement of margins is recommended. Poorly designed pontic teeth and partial dentures enhance plaque accumulation and increase difficulty in plaque removal.

4.4 CHEMICAL MEASURES

Antimicrobials

The use of antimicrobial drugs to either prevent plaque formation or inhibit the activity of specific bacterial strains within plaque is another potential means of plaque control. If successful, this method would have the attractiveness of requiring minimal cooperation and dexterity of the individual as compared to those mechanical plaque control measures that require rigorous individual activity daily. The desired features of antimicrobials include lack of oral or systemic toxicity, poor absorption from the alimentary tract, substantivity (binds to substrate), low induced drug resistance, and cosmetic acceptance (104).

Despite the potential of antimicrobial plaque inhibitors, there has been insufficient new research to change previous conclusions about them. Chemotherapeutic agents for plaque control appear to have a promising future, but none of the existing antimicrobials, Table 4.1 (104,105), has been shown to fulfill the necessary requirements and, other than fluorides, none should be used on a long-term basis. Chlorhexidine may be indicated for certain high-risk groups such as the immune-suppressed, severely handicapped, and postsurgical patients, but chlorhexidine has less effect on gingivitis than on plaque (106,107).

Imunization

Since dental caries and periodontal disease are infections, research interest in developing preventive vaccines is understandable. However, there has been little recent research to justify a change in the conclusions made seven years ago. Prevention through immunization remains an attractive and promising approach to the prevention of dental caries and of at least some forms of periodontal disease. However much more needs to be known about the biology of caries and periodontal disease immunity for vaccines to become a reality. In this regard, recent work implicating specific subgingival microorganisms is an important step, but safe, effective vaccines for clinical use will not be available for many years.

4.5 SUMMARY

Recent findings about bacterial plaque and the epidemiology of periodontal disease, and the anticipated results of current research into these areas have important implications for the future of plaque control methods used by the individual and professional.

At present there is no scientific basis for recommending an ideal number of toothbrushings per day, nor for the superiority of any one toothbrush or toothbrushing method. The effectiveness of brushing and the characteristics, motivation, diligence and dexterity of the toothbrush user are more important.

Most individuals do not have the means, ability, or dedication to remove plaque sufficiently from their teeth to reduce caries incidence, but they can apply fluoride toothpastes which reduce caries.

TABLE 4.1

ANTIMICROBIALS TESTED FOR PLAQUE CONTROL

Antibiotics:		actinobolin, bacitracin, chlortetracycline, erythromycin, gramicidin, kanamycin, neomycin, niddamycin, penicillin, polymyxin B, spiramycin, streptomycin, tetracycline, vancomycin
Benzophenanthridine alkaloid:		sanguinarine
Bisbiguanides:		alexidine, chlorhexidine
Bispyridines:		octenidine
Enzymes:		proteases, mucinase, dextranase, glucondase, viokase
Halogens:	chloride-	oxychorosene, chloramine-T
	fluoride-	stannous, sodium
	iodide-	iodine and iodophors
Metal ions:		zinc, tin, copper
Metronidazole		
Oxygenating agents:		perborate, peroxide
Phenolic compounds:		phenol, betanaphthol, hexylresorcinol
Quarternary ammonium compounds:		benzethonium chloride, cetylpyridinium chloride, domiphen bromide

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Sources: Newbrun 1985 (104); Kornman 1985 (105).

In a healthy mouth, gingivitis can be prevented by the available means of plaque removal, but the dedication and perseverance for continued control is difficult to maintain. This is discussed further in Chapter 7 on Dental Health Education.

Very frequent removal of plaque by professionals, which is very costly, reduces caries, gingivitis and periodontitis, but semi-annual or annual prophylaxes have not been found to prevent caries or gingivitis. Nor is prophylaxis necessary before topical fluoride application.

Prevention of loss of periodontal attachment is very difficult to assess at present because the loss is believed to be episodic and unpredictable, and methods for its detection are very limited and insensitive.

4.6 RESEARCH NEEDS

Because of the equivocal findings in the literature regarding some facets of plaque control, and the lack of information in others, the following research needs are identified:

1. Further research is needed to clarify the equivocal results now available about optimal toothbrushing frequency and, as well, about the best toothbrushing method/brush combination for various groups.

2. With dentifrices claiming to prevent the formation of supragingival calculus, the two following areas need to be studied: i)their long-term effectiveness on the general population; and ii) the consequences if professional subgingival calculus removal is ignored as a result of the diminished supragingival calculus. It would also be interesting to conduct community-based clinical trials using children having the typically lower caries experience of developed countries to see how the cariostatic effect of these new calculus-inhibiting dentifrices compares with regular fluoride dentifrices after two or three years.

3. Further research is needed to clarify the efficacy of interdental cleaning by individuals and by therapists for varying interdental and subgingival anatomy and space. These studies should consider costs and benefits, as well as manual dexterity, habit formation and the appropriate ages both for parents to start flossing their children's teeth and for self-flossing to begin.

4. Methods need to be developed to identify high-risk groups and high-risk sites, as well as more specific data on prevalence and incidence of dental diseases. What is the level of plaque and gingivitis that a particular individual can tolerate without loss of attachment, and what are the microbial and host characteristics of individuals with poor oral health despite good plaque control and vice versa?

5. Research to clarify the relative contribution of toothbrush, toothbrushing technique and dentifrice to cervical abrasion is especially important in view of the likelihood of greater longevity of dentitions. For the same reason, further clinical trials to determine the best agent for treating cemental and dentinal hypersensitivity are needed.

6. Further investigation of oral irrigators is warranted to determine if complete douching of interdental pockets with washing out of unattached microorganisms is possible without tissue penetration. In addition, the ability of oral irrigators to carry antimicrobial agents subgingivally to reduce the pathogenicity of subgingival plaque should be studied.

7. Long-term studies are required to confirm more satisfactorily the value of professional dental prophylaxis and its required frequency in relation to varying levels of oral hygiene, in relation to use of other preventives such as fluorides and fissure sealants, and in relation to the prevention and control of caries and periodontal diseases.

8. Regarding antimicrobial agents for plaque control, research should be undertaken concerning:

   i) development of new antimicrobials for lifetime use in the oral cavity for the control of plaque-mediated diseases, especially in high-risk individuals;

   ii) effective modes of oral delivery and distribution of antimicrobial agents, especially to high-risk sites; and

   iii) the long-term effects of partially or completely suppressing the bacterial flora.

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CHAPTER 5

CHAPTER 5

DIET AND DENTAL HEALTH

R.C. Burgess

Tissues in the oral cavity can be affected by both the systemic effect of nutrition and by the local effect of the diet:

i) During the formation and remodelling of dental tissues the diet can influence the type and quality of nutrients reaching the formative cells via the blood supply;

ii) After they are formed and become exposed to the oral environment, dental tissues come into local contact with ingested foodstuffs and can be affected directly by these foodstuffs or by metabolites produced from food constituents through the action of plaque bacteria.

5.1 THE ROLE OF NUTRITION IN PERIODONTAL HEALTH

It is universally agreed that periodontal disease is primarily a morbid response of the periodontal tissues to local irritants produced in the dental plaque (1,2,3). A number of epidemiological studies (4,5,6) have demonstrated close relationships: a) between the amount of dental plaque and the degree of gingival inflammation; and b) between the duration of poor oral hygiene (expressed as age) and the accumulated periodontal breakdown.

It is also widely believed that the tissue response to the dental plaque irritants is modified by conditions within the host, namely nutritional status, hormonal balance and host-defense capabilities (1,3,7,).

The periodontal or supporting structures of the teeth -- alveolar bone, periodontal ligament and covering gingiva -- are characterized by continual metabolic activity and turnover throughout life (8). Thus, the maintenance and repair of these tissues, like similar tissues elsewhere in the body, continuously require an adequate supply of macro-and micro-nutrients for cell division, protein synthesis and energy metabolism. For instance the permeability of oral epithelium to foreign protein or polysaccharide is increased in animals with nutrient deficiency (9,10,11). It is impossible to avoid the conclusion that health of the periodontal tissues requires the nutrients provided by a sensible diet, i.e. that the nutritional requirements for periodontal health are no less than those required for good general health (1,3,7,12). In fact, it has been suggested that periodontal tissues may have a greater need for some nutrients due to rapid turnover, constant bacterial challenge and higher rate of metabolism when compared to other tissues (3,13,14,15).

A number of epidemiologic studies have found that people from the lowest sociological class who share a poor nutritional status also have the greatest susceptibility to periodontal disease, even after due allowance is made for oral hygiene and age factors (6,16,17,18). It is not clear whether this greater susceptibility to periodontal disease is due to generalized malnutrition and debilitation or to a lack of specific nutrients. However, there is some concern that deficiencies of several nutrients, e.g. vitamin C, folic acid, protein, calcium, zinc and iron, may aggravate periodontal disease.

Vitamin C

Vitamin C is required for the formation and maintenance of normal bone and other connective tissues of the periodontium (1,19). In scorbutic guinea pigs, an increase in permeability of oral epithelium associated with inflammation permits the passage of bacterial products into the tissues (20). Vitamin C deficiency in non-human primates has been found to increase the permeability of sulcular epithelium two to three weeks before the development of scorbutic gingivitis (9). In humans the sulcular epithelium permeability was found to be inversely related to the vitamin C concentration in the gingival tissue (21). It has been repeatedly stated (as a result of animal experiments) that deficiency of vitamin C, of itself, will not cause gingivitis or periodontal breakdown unless a local irritant (plaque) is present (1,19,22). However, the clinical reality is that there is usually enough dental plaque deposit in most people to incite local irritation of periodontal tissue which vitamin C deficiency could then accentuate. This must be particularly true for impoverished people in developing countries who have poor oral hygiene and limited access to vitamin C-containing foods.

Most individuals in more affluent countries appear to have a vitamin C intake that is adequate for good periodontal health. A report based on the 1970-72 Nutrition Canada National Survey found that the average vitamin C intake by Canadian adults was 190 per cent of the 1983 Recommended Nutrient Intake (RNI) for that vitamin (23). Data from the NHANES I study in the United States indicated a mean vitamin C intake which was 115 per cent of the 1968 NRC-RDA* (24). Analysis of diet records from 100 periodontal patients by Osborn et al.(25) showed an average ascorbate intake of 162 per cent of RDA**. Vogel et al.(26) reported similarly high mean intakes of 180 per cent of RDA** for a sample of the adult population (N=1222) of undetermined periodontal status and 150 per cent of RDA for 35 patients with moderate to severe periodontal disease. The above results (23-26) show that both the general population and individuals with periodontal disease have vitamin C intakes well in excess of the current RNI values (60 mg and 45 mg/day for men and women, respectively).

The study of the general population by Ismail et al.(24) also showed that vitamin C intakes in excess of the current American RDA (and Canadian RNI) levels were not associated with better periodontal health. Not surprisingly, clinical trials agree that daily supplements of 300-500 mg vitamin C do not reduce the severity of gingivitis, tooth mobility, sulcus depth or gingival vitamin C levels in otherwise healthy individuals with adequate diets (27-30).

However, there are indications that some individuals, within the general population, may have impaired periodontal health due to vitamin C intakes considerably below the recommended level. A recent study in males with suboptimum plasma vitamin C levels reported that a 750 mg per day vitamin C supplement (in a multivitamin preparation) decreased gingivitis scores in seven days (31). In addition, long-term vitamin C supplementation of individuals with suboptimal intake (10-25 mg per day) delayed the recurrence of inflammation after thorough removal of local irritants (27). Cheraskin and coworkers (32) claim that vitamin C supplementation at the time of dental prophylaxis will improve the rate of healing beyond that produced by the prophylaxis alone. This improvement was greatest in the patients with the lowest initial plasma vitamin C levels (32). While these studies (31,32) suggest a benefit from vitamin C supplementation of individuals with suboptimal vitamin C status they are not conclusive because the number of individuals in the supplement groups was small and neither study provided data on the vitamin C intake of the participants.

Although the vitamin C intake of the population as a whole appears high enough to support periodontal health there may be individuals (see above) and specific groups such as Inuit, elderly males and alcoholics (23) who are at risk due to chronically low intake of this vitamin. Some effort should be made to study periodontal status in such individuals and groups and to determine the benefit of increased vitamin C intake. The value of vitamin C supplementation after prophylaxis or periodontal surgery should also be investigated further in randomized, controlled clinical trials and with proper attention to the usual vitamin C intake and tissue vitamin C levels of the participants.

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* Canadian 1983 RNI and United States 1968 NRC-RDA values for vitamin C are similar.

** All United States data has been recalculated relative to the 1968 NRC-RDA values.

Folic Acid

In the last few years there has been growing awareness that dietary folic acid levels may be inadequate, particularly for women who are pregnant or taking oral contraceptives. Vogel and coworkers reported a series of placebo-controlled studies on the influence of folic acid on periodontal tissues (3,33,34). In one study, folic acid (4 mg per day) was ingested by patients with excellent gingival health who refrained from oral hygiene for two weeks on one side of their mouths (33). The folate group showed less inflammation as indicated by decreased gingival exudate and bleeding index despite the same plaque accumulation and despite the same plasma folic acid levels as in the controls. The authors hypothesized that an end-organ deficiency of folic acid in gingiva must have existed even though systemic levels as measured by plasma values were within normal limits. Support for this concept was obtained in a second study where mouth rinsing with 0.1 per cent folate increased gingival folate levels five-to-tenfold and significantly reduced gingival inflammation as compared with the placebo group (34). Other clinical studies indicated that folic acid supplementation reversed megaloblastic changes and inflammation in sulcular epithelium that are associated with the use of oral contraceptives (3). This reversal of cytological abnormalities by folate was accompanied by decreased in vitro permeability of the sulcular epithelium and significant reduction in gingival inflammation as measured by gingival exudate. Finally, Pack and Thomson have evaluated the effect of folic acid tablets, rinses or placebo on gingivitis in women during the fourth (35) and eighth (35,36) month of pregnancy. The authors concluded that twice-daily rinses with 0.1 per cent folate solution were significantly more effective in reducing gingivitis than either the folate supplement or the placebo (35,36). However, the data histograms presented in the second study (36) show similar decreases in the gingivitis for the folate rinse and tablet groups. These interesting findings should be followed up with a large scale clinical trial(s) on the effect of folic acid administration on gingivitis, in which the dietary, gingival and systemic levels of folate are accurately monitored.

Protein

Dietary protein is necessary to provide a continuing supply of the amino acids required for synthesis of new protein particularly for tissues in a continuous state of replacement or repair, such as blood-cells, oral and gut epithelium and periodontal connective tissue. Previous reviews (1,37) have summarized the animal studies which showed that protein-calorie malnutrition will result in thinning of alveolar bone and periodontal fibers and will also impair the healing of gingival and other wounds.

Severe protein deficiency is often seen among poor people in underdeveloped countries and has been associated with increased risk of periodontal disease, acute necrotizing ulcerative gingivitis, and even cancrum oris (17,18). It is possible that periodontal disease may also be more severe among high-risk groups in industrialized societies, for instance, alcoholics, drug addicts, the desperately poor and others who consume diets low in protein and, in particular, low in animal protein. This hypothesis has not been proven.

Nevertheless, protein malnutrition cannot be invoked as a cause of the widespread periodontal disease among Canadian adults since their average daily protein intake is well above the recommended level (23). Similar observations have been made in the United States for periodontal patients (25,26). For this reason little credence is placed in earlier reports that gingivitis could be markedly reduced in apparently healthy young adults by consumption of a low carbohydrate, high protein diet for only four days (38).

Finally, one must note the surprising dearth of human studies dealing with the influence of dietary protein intake on gingival or periodontal status in humans. There is a need for both epidemiologic studies and controlled clinical trials on the effect of protein supplements on periodontal status of the high-risk groups previously mentioned.

Calcium and Phosphorus

In 1968 Henrikson reported that diets low in calcium and/or with a low Ca:P ratio would produce extensive generalized bone loss and periodontal disease in dogs, as a result of nutrition-related secondary hyperparathyroidism (39). Henrikson and coworkers (40) later published a poorly-documented study in ten humans with "periodontal disease" and a low mean calcium intake of 325 mg per day (as estimated by dietary recall). They reported that supplementation with 1 g per day calcium (no controls) reversed bone loss and reduced gingivitis, pocket depth, and calculus (40). The authors concluded that excessive resorption of alveolar bone, due to calcium deficiency, is the primary event in periodontal disease. They stated that even the recommended intake of 800 mg Ca per day was inadequate to prevent periodontal disease. Independent studies in dogs, rats and mice using diets low enough in calcium (and Ca:P ratio) to cause secondary hyperparathyroidism and loss of alveolar bone density found that such diets had no effect on gingivitis or periodontal disease (41,42) or on vertical alveolar height (42,43). These results (40-42) indicate that low dietary calcium intake (and associated low Ca:P ratio) is not a primary cause of periodontal disease in animals and may not be even a contributory factor. A recent randomized, controlled study in humans with moderate to severe periodontal disease found that supplementing the test group (n=31) with 1 gm Ca per day did not alter gingivitis, bleeding index, tooth mobility, alveolar bone level or alveolar bone density when compared to the placebo group (n=29) (44). One-third of the participants in each group had dietary calcium intakes below 800 mg per day while two-thirds had intakes slightly above this value. These findings indicate that inadequate calcium intake is not the main cause of typical periodontal disease in humans despite the high phosphorus intakes found in modern diets. The data imply that calcium intakes of about 800 mg per day are adequate for periodontal health. However, further epidemiological and supplementation studies should be carried out on periodontal disease in humans who have long-term calcium intakes of less than 600 mg per day with or without low dietary Ca:P ratio. On a related topic, it is also possible that low calcium intakes might accelerate alveolar ridge resorption in patients who have had recent extractions (45,46).

Zinc

Zinc is required for the activity of many enzymes, notably those involved in nucleic acid metabolism and protein synthesis. Supplementation of zinc-deficient animals increases the rate of wound healing (47,48) including epithelialization of gingival wounds (48). The Canadian RNI for zinc is eight and nine mg per day for adult females and males respectively (49). This need would be met by a sensible diet. However, there is some concern that individuals who restrict their intake of zinc-rich foods such as red meat, eggs, poultry, shellfish and dairy products may inadvertently reduce their zinc intake to a marginal level (13). This concern is even greater in the United States where the Recommended Daily Allowance (RDA) for zinc is even higher -- 15 mg per day for adults. Thus, there is a need to study whether low intakes of zinc by some members of the population could be a contributing factor in periodontal disease.

Iron

This element deserves special mention because iron-deficiency anaemia is the most common nutrient disorder in both developing and industrialized societies (50). The risk of deficiency is greater in teen-aged and adult females due to the additional demands for iron which result from menstruation and pregnancy (49). The central role played by iron-containing molecules in oxygen transport to tissues and in oxidative metabolism within cells means that iron deficiency can cause a general impairment in tissue metabolism and host resistance. Since iron deficiency is fairly common in the population, dentists should ensure that it is not a complicating factor in patients whom they are treating for periodontal disease (13).

5.2 LOCAL EFFECT OF DIET ON PERIODONTAL HEALTH

In experimental animals, foods which are soft or readily impacted into the gingival sulci encourage gingival inflammation, loss of epithelial attachment and resorption of crestal bone (1). A hard diet which requires vigorous chewing exerts a strong local influence on the severity of gingivitis and periodontal disease (51-53). However, in humans the addition of fibrous foods, such as carrots or apples, to the usual diet does not decrease plaque accumulation or gingivitis (54-56). The reasons for the lesser effect of diet consistency in humans are probably two-fold. The usual human diet is not as soft in consistency as the minced or powdered diets used for the control in the animal studies and may, itself, provide some modest benefit to the gingiva. More importantly, carrots and apples, while representative of the firmer foods eaten by humans, would not require the same vigorous chewing as the raw cartilaginous trachea and rock-hard chow used in the animal studies. Nevertheless, it is clear that gingivitis and periodontal disease in human populations cannot be significantly reduced by adopting a firmer diet; the removal of plaque and food debris by oral hygiene procedures is essential.

Other animal studies have shown that frequent sucrose consumption can intensify plaque accumulation, gingival inflammation and bone loss (57-60). In human volunteers who refrained from oral hygiene (61,62), and in those who did not (63,64), frequent sucrose ingestion increased plaque accumulation. Three of these studies found that the frequent sucrose ingestion also increased gingivitis scores (63-65) whereas one study did not (62). Epidemiologic studies of gingivitis and periodontal disease have not included frequency of sugar ingestion as a factor for analysis. It has been stated that dietary constituents are unlikely to affect subgingival plaque metabolism since they cannot gain access to this plaque and nourish it (3). However, the results cited above indicate that patients should be cautioned that frequent sugar consumption will increase plaque accumulation and may aggravate gingivitis.

5.3 PREVENTION OR CONTROL OF PERIODONTAL DISEASE BY DIETARY MEANS

While it is universally agreed that dental plaque accumulation is the primary cause of periodontal disease, nutrition is believed to be a modifying factor (1,3,7). A nutritionally adequate diet is required for the continued synthesis and repair of periodontal tissues and for the maintenance of host resistance (1,3,7). Evidence to date indicates that the current nutrient intake of the population as a whole is adequate to meet these needs. Some clinicians have advocated vitamin, protein or mineral intakes in excess of recommended intakes as a prophylactic measure for the prevention or control of periodontal disease (32,38,40,66,67); however, as we have seen, there is little or no scientific evidence to support this practice. Our efforts should be directed toward individuals and groups who may be at risk of worsening their periodontal condition due to chronic low intake of nutrients such as vitamin C, protein and calcium. In addition, there should be further research into the relationships between folic acid, zinc and iron intakes and periodontal health.

Considering the high prevalence of periodontal disease in the population, some strategy is required in the use of nutritional guidance. The following course of action is suggested:

i) All dental patients, and particularly those with periodontal disease, should be informed of the role that adequate nutrition plays in the maintenance of periodontal tissue which can resist infection and can repair normally. Current patient education materials dealing with periodontal disease could be improved by the addition of information on nutritional requirements for periodontal health.

ii) The dietary practices of high-risk patients should be evaluated, and these patients should be given dietary counselling where required. High-risk patients would include those with severe periodontal disease, with a history of low resistance to general infection or wound healing, and those with a poor response to conventional periodontal treatment or those slated for extensive periodontal surgery. Periodontal patients with unusual dietary habits or suspected marginal nutrient intakes should also be included in the high-risk group. Specific biochemical tests should be considered for confirmation of any deficiencies suggested from analysis of dietary records.

iii) The application of dietary analysis and counselling to all periodontal patients is not justified at the present time. However, it could become feasible as rapid and simple methods become available for dietary screening of patients to identify those with potential nutrition inadequacy. In addition, there should be proof, through clinical trials, that dietary analysis and counselling are cost-effective when applied to periodontally involved patients identified as high risk through dietary screening.

5.4 NUTRITIONAL EFFECTS ON CARIES SUSCEPTIBILITY

Nutrition during the period of tooth formation exerts a profound influence on subsequent caries susceptibility. The best example of this is the need for an adequate supply of fluoride during mineralization and pre-eruptive maturation of the teeth in order to form caries-resistant enamel. The fact that posteruptive fluoride exposure from dentifrices, rinses, and topicals can reduce the caries rate has led to speculation that the effect of fluoride is essentially topical (posteruptive) rather than nutritional (preeruptive) (68,69). However, several earlier clinical studies indicated that the maximum benefits from water fluoridation could only be achieved when the individual begins the fluoride ingestion one to three years before tooth eruption (70-72). Recent studies in Britain and Ireland (73-75) and the United States (76) showed that, despite the general decrease in caries in all areas, the caries rate is still at least 35 per cent lower in fluoridated communities than in non-fluoridated ones. These results (73-76) suggest that a nutritional (pre-eruptive) need for fluoride still exists if the caries rate is to be minimized.

Other trace elements may influence caries susceptibility in humans. The ingestion of food or water with high selenium content has been associated with higher caries incidence (77,78). By contrast high concentrations of strontium (79,80) and vanadium (78,81) in the diet and of strontium in enamel (82) have been associated with lower caries incidence. Contradictory associations have been reported for lithium, molybdenum, copper and manganese (83,84). However, in animal experiments only strontium has shown a consistent inverse relationship with dental caries (83,85). There appears to be a consensus that none of these elements exerts the degree of influence on dental caries that fluoride does.

In fact, there has been a general belief that nutritional (systemic) factors, aside from fluoride, do not exert any significant effect on susceptibility to dental caries (86,87). Some have noted that caries is actually less in areas of gross malnutrition than in areas of adequate or over-nutrition. This argument is superficial since these malnourished people are not provided with frequent cariogenic (sugar) challenges as are people in more affluent societies. Moreover, there are reports from several countries that children who suffer from protein-calorie malnutrition during tooth development will exhibit enamel hypoplasia when the teeth erupt and that these teeth will have a much greater susceptibility to caries (88-90). Experiments in rats (91,92) indicate that the primary nutritional defect is lack of protein rather than lack of calories. Rat pups raised under conditions of protein deficiency will show permanent abnormalities in enamel and salivary gland structure as well as higher caries susceptibility. This is an excellent example of the long-term impact of a nutritional deficiency during the "critical stage" of cell differentiation and tissue formation (93). Other animal studies suggest that iron deficiency during enamel formation will lead to higher caries susceptibility (94,95). Thus, there is increasing evidence that nutritional factors other than fluoride can influence caries susceptibility.

More research in this area is imperative when one considers the massive caries problem that would occur in developing countries if the increasing use of sugar is superimposed on dental tissues malformed during periods of prior nutritional deficiency.

5.5 LOCAL EFFECTS OF DIET ON CARIES SUSCEPTIBILITY

An experiment with tube-fed rats (96) has shown that dental caries will not occur unless the cariogenic diet comes in contact with the teeth. In addition, caries is minimal unless the diet contains fermentable carbohydrate, primarily sugars. The Hopewood House (97) and Turku (98) studies showed that a low caries increment would occur in humans eating a diet low in refined sugar but containing starches and natural sugars from fruit.

All of the common sugars -- sucrose, glucose and fructose, are readily utilized for energy purposes by plaque bacteria, yielding acid end products which can demineralize the teeth (99-101). Limited evidence from animal and human studies suggests that sucrose may be slightly more cariogenic than the other sugars (102-104, 98), presumably because certain plaque bacteria use it to synthesize adhesive polymers -- glucans and fructans. These polymers (particularly insoluble glucans) permit the accumulation of thicker plaques, most noticeably on free smooth surfaces (61-64, 105); however, this point should not be overemphasized since these are the same tooth surfaces from which plaque is most readily removed by oral hygiene procedures. The evidence indicates that sucrose, glucose and fructose are all highly cariogenic.

Intraoral Sugar Availability

Stephan (106) and later Konig (107), found that rats had low caries scores when they were restricted to eating their sugar-containing diet 12 times per day or less. When the frequency of sugar consumption was increased above 12 meals per day, or was unrestricted, their caries scores increased dramatically. Bowen confirmed (108) these observations and noted further that rats fed only three meals per day of sugar-containing diet had no smooth surface caries and virtually no fissure caries. These results suggest that the natural defense mechanisms in the mouth can, up to a point, repair the damage done by a moderate duration or frequency of sugar exposure.

A similar conclusion was reached in the famous Vipeholm Study (109) in humans. Up to 300 gm of sucrose (about three times the average Canadian daily intake) dissolved in water could be ingested per day with the regular meals without significantly increasing dental caries. However, when 40-120 gm of this daily sugar intake was consumed between meals in the form of caramel or toffee, the caries rate, on both coronal and root surfaces, increased dramatically. In a companion study, Lundquist (110) noted that the caries rates in these Vipeholm groups were fairly well correlated with the number of hours in the days that salivary glucose levels were elevated (by the sugar and candies). The Vipeholm study has been criticized because the control and sucrose-containing diets were assigned to separate asylum wards and not randomly allocated to individuals. However, the design did assure rigid control over the diets consumed. In addition, a pre-test control period showed that all groups had a low caries increment when fed a low sucrose diet.

Recent animal studies support the importance of frequent sugar exposures but emphasize that a given frequency of sugar exposures is more damaging when it is distributed throughout waking hours than when it is concentrated into a part of the day (111,112). It is important to note that in these animal studies the sugar-containing meals are all identical in composition and are presented to the animals for the same length of time.

The clear and dramatic effect of frequency of exposure to sugar on dental caries that is observed in human and animal experiments (106-112) contrasts sharply with the less dramatic (113-115) and sometimes non-significant (116,117) association observed in cross-sectional epidemiologic studies, even when multifactorial analysis is used (116). Recently, Rugg-Gunn and his colleagues (118) carried out a well-designed longitudinal epidemiologic study on the association between the two-year DMFS increment and the food usage patterns as determined by five three-day food diaries collected over the study period. They found that the total daily weight, but not the frequency, of sugar consumption was significantly associated with caries increment. The daily weight of between-meal sugars showed an even higher correlation with caries increment. However, the authors noted that the correlation coefficients, though statistically significant, were not large (0.10-0.15). They stated that high intra-individual variation was likely to have caused serious underestimation of the strength of the relationship between diet and caries in this and other correlation studies using epidemiologic data. The same point has been raised by Jacobs et al.(119) with regard to the use of correlation analysis in studies of diet and serum cholesterol. Rugg-Gunn et al.(118) cited several important sources of method error in epidemiologic correlation studies including: a) the difficulty of accurate caries diagnosis, particularly in areas with low caries rates; and b) the problem of accurately assessing the diet of several years on the basis of a single 24-hour recall or three-to-five day food diary.

However, there are additional problems related to the use in caries research of "frequency" of exposure to sugar-containing foods. Sreebny (120) has pointed out that many exposures to sugar might be overlooked because sugar is so widely hidden in modern convenience foods. Secondly, both weight and frequency of sugar intake are at best very crude estimates of the cariogenic challenge. All sugar-containing foods are not equal in cariogenic potential (108). In addition, controlled experiments in animals and humans make it clear that the caries process is most strongly influenced by the proportion of the day that sugar is present in the mouth (106-112). Thus, cariogenic potential of a specific food may be expressed quite differently depending on whether the food is consumed rapidly or ingested gradually over an extended period of time.

Assessment of Cariogenic Potential of Foods

The most convincing way to demonstrate the cariogenic potential of a specific food would be to carry out a two-to-three year randomized clinical caries trial in which the control group ate their usual diet while the experimental group ate their usual diet supplemented several times per day with the food or beverage in question. Even if ethics committee approval and informed consent could be gained for such a study it is inconceivable that the subjects could faithfully use the test food/beverage several times per day for the required two or three years.

For the above reasons determination of the cariogenic potential of foods must involve shorter term methods of evaluation. These methods range from intraoral tests of cariogenicity, demineralization or plaque pH response in humans to animal caries models and laboratory abstractions of the caries process such as the "artificial mouth". Since current and future research on diet and dental caries will utilize these techniques they are discussed below:

A) The Intraoral pH Response to a test foodstuff can be measured in several ways: i) by inserting a small pH touch electrode into buccal or interproximal plaque before and at regular intervals for at least 30 minutes after ingestion of the test food (121); ii) by harvesting samples of plaque before and after ingestion of the test food and measuring their pH outside the mouth (122), and iii) by using an indwelling telemetry system involving a special partial denture or bridge which carries a pH sensing electrode just below the contact area with the adjacent natural teeth (123). The pH can be monitored continuously before and after ingestion of the test substance. In all three methods oral hygiene must be avoided for at least two days before the pH measurements can be reliably carried out.

The absolute plaque pH response to a standard one minute rinse with 10 per cent sucrose solution is much greater with the indwelling electrode system than with the touch electrode or harvesting methods (124,125). Nevertheless, all three methods give similar relative results when test foods are compared with positive (sucrose) and negative (sorbitol) standards (126,127). In Switzerland, foodstuffs which do not cause the indwelling electrode pH to drop below 5.7 can be labelled "safe for teeth" (100). Those which do cause a pH drop below 5.7 are considered cariogenic unless proven otherwise. It should be noted that some foodstuffs contain other factors which minimize demineralization even when the pH drops considerably (128,129).

B) The Intraoral Cariogenicity Test (ICT) of Koulourides (101), while much more time-consuming than plaque pH tests, can identify foods or beverages that are non-cariogenic despite their ability to lower plaque pH. This test avoids the ethical and dental problem of exposing the subjects' teeth to repeated cariogenic challenge and provides a sensitive estimate of caries progression over the seven-day test period. Patients wear one or two blocks of polished bovine enamel in each buccal flange of a partial or full denture or modified Crouzat appliance. The blocks are covered with dacron mesh to encourage bacterial plaque accumulation. The appliances are removed from the mouth four or more times per day and the blocks on one side are immersed in a negative control (distilled water) or positive control (10 per cent sucrose) while the blocks on the other side are immersed in the test solution. The background variation due to the subjects' diet can be minimized by placing the appliance in the control and test solutions whenever meals and snacks are consumed.

The ICT caries is evaluated as microhardness change by measuring the degree of penetration of a diamond indenter dropped onto the enamel surface. Recently, microhardness or microradiographic density have been measured across enamel sections cut perpendicular to the enamel surface (130,131). This procedure, while more time consuming, does allow more precise measurement of mineral loss in lesions which extend deep into the enamel.

The ICT system provides good approximation of the natural caries situation in that the enamel blocks, covered with a naturally formed plaque of oral microorganisms, are exposed briefly and extraorally to the test substrates and then for the remainder of the day to the cleansing and remineralizing action of saliva. The short experimental period of seven days and minimal interference with diet makes the experimental protocol tolerable to the participants. It is obvious that the present model is best suited to the testing of solutions and food suspensions. The model can be modified for solid foods, including chewing gum. These must be tested intraorally using different experimental periods for the test food and control (132). Alternatively a modified appliance can be used which permits the control enamel blocks from one side of the arch to be removed and placed in a moist chamber while the test blocks remain in the mouth and are exposed to the test food.

C) The Intraoral Demineralization Test (IDT) of Brudevold et al.(133) uses enamel blocks carried in a palatal appliance and covered by a layer of laboratory-grown bacteria, usually S. mutans. Demineralization is measured by the ultrasensitive method of iodine permeation. This in turn permits an experimental period of only two to three hours during which the test food or beverage (or control) is consumed once or, at most, twice. The intraoral aspect of the test allows for normal consumption of the test food or beverage and for removal of substrate from the mouth by salivary action. The IDT method appears to be good for measuring the demineralizing potential of foodstuffs (134) but is less satisfactory for evaluating their ability to stimulate remineralization. The main shortcoming of the IDT is that the iodine permeation measurements are tedious and very difficult to perform accurately.

D) Animal Caries Models have been evaluated in recent collaborative studies involving several laboratories. It has been found that foods which are non-cariogenic in humans are non-cariogenic in rats and substances which are cariogenic in humans have a similar effect in rats (135). When animals superinfected with S. mutans are provided the test diets at controlled frequency (at least 12 times per day), the precision of the method is sufficient to categorize foods into three general categories of no, low and moderate to high cariogenic potential (108,135,136). Such assays should include confectioners' sugar as a positive control and also an appropriate negative control which provides calories but is non-cariogenic (137). In addition, the animals must be given a nutrient supplement twice a day either by stomach tube or by a timed feeding device (137).

E) The Artificial Mouth is the general name used for in vitro systems in which enamel covered by a bacterial plaque is exposed to cariogenic challenge by a solution, extract or puree of the foodstuff in question (138,139). These systems represent a considerable distortion of the caries process in that cariogenic substrate is present for prolonged periods of time and the opportunity for saliva to support remineralization is brief or absent altogether.

There are numerous other in vitro caries methods involving the placement of enamel slabs or sections in bacterial suspensions, acidified gels or solutions. None of these methods is adequate for testing the cariogenicity of foods or beverages but may be useful to identify potentially anticariogenic components in foodstuffs.

The recent Consensus Conference on Methods for the Assessment of the Cariogenic Potential of Foods (140) recommended the use of a sequence of tests for categorizing foods and beverages into the following cariogenicity groups:

i) No Cariogenic Potential

Any foodstuff which, in two independent laboratories, does not reduce plaque pH (see A above) more than does a standard sorbitol rinse (negative control) would be considered to have no cariogenic potential, without further testing. The test system must show a pH fall of at least one unit in response to a challenge with 10 per cent sucrose solution.

ii) Low Cariogenic Potential

A foodstuff which causes a greater pH decrease than a standard sorbitol rinse (negative control) could be classified as having low cariogenic potential if its Caries Potential Index (108) in the animal model system (see D above) was 0.4 or less. Certain foodstuffs which are difficult to assess in the animal model such as beverages and chewing gum could be assessed in the human IDT or modified ICT systems using similar criterion (see B and C on p.58).

iii) Moderate to High Cariogenic Potential

The remaining foods and beverages which lower plaque pH would fall into this category. There is reluctance to divide foodstuffs further into moderate and high cariogenic potential groups by the animal model or IDT or ICT systems since the clinical significance of such a subdivision is unclear at the present time.

Cariogenicity of Foods

It has long been considered that starch has little or no cariogenicity since both ancient and contemporary peoples living on a diet essentially devoid of sugar but rich in starch experienced minimal caries (87). This argument, while appealing, is not scientifically strong if one considers that in these populations, starch is usually consumed at mealtimes only. Under these conditions even sucrose might appear to have low cariogenicity (see Vipeholm study). While starch is composed of glucose, the sugar units are linked to form a polymer which is not readily diffusible into plaque and is not directly fermentable by bacterial glycolytic enzymes. However, the saliva contains a high concentration of the starch-splitting enzyme, amylase, and starches which are retained on or between the teeth and in pits and fissures could be split by amylolytic action to provide glucose to the adjacent plaque, thereby permitting acid production and demineralization (141,142).

Raw starches appear to have low cariogenicity as judged by animal caries tests (143,144), pH response of buccal plaque in man (99) and intraoral demineralization in man (134). However, cooked, pregelatinized and other modified starches so widely used in the food industry, do give rise to considerable acid production in the mouth (99,100,145,146) and are cariogenic in rats (106,147). These observations draw attention to the probability that food products made with cooked or modified starches would be moderately cariogenic even if sweetened by a totally non-cariogenic sweetener. Usually such food products are sweetened by sucrose and could be more cariogenic than the sucrose alone, due to increased retentiveness provided by the starch (128,148).

There is an urgent need to reappraise the cariogenicity of refined and modified starches now being incorporated into convenience and snack foods which are likely to be consumed between meals.

Food Retentiveness and Oral Clearance

Since the Vipeholm study, it has been an article of faith that sugar-containing foods and confections which adhere to the teeth will be more cariogenic than those which do not (109). Somehow this has been distorted into the view that sugar in solution is not very cariogenic, presumably because it is rapidly cleared from the mouth (12). However, studies with indwelling pH electrodes indicate that the plaque pH falls below 5.0 when exposed to a single challenge with sucrose solution. Similarly, sucrose and other sugar solutions are very cariogenic when tested in the IDT and ICT systems in humans. Moreover, sugars in solution, such as beverages, are usually consumed as a series of sips over a period of time. Thus, the actual cariogenicity of sugar in solution may be greater than is suggested by its cariogenic potential, or "gram for gram" cariogenicity (149), if its pattern of consumption results in the prolonged presence of sugar in the mouth. In contrast, it should be noted that sipping sweetened beverages through a straw can markedly reduce the exposure of the teeth to the beverage (150,151). These comments underscore the fact that frequency of sugar ingestion is a very crude estimate of the actual cariogenic challenge. It is essential in counselling patients who have a real or potential caries problem to determine not only the type and frequency of sugar exposures but also the precise manner in which these foodstuffs are used.

Without doubt, the most extreme example of the effect of delayed oral clearance and prolonged cariogenic challenge is nursing bottle caries. This characteristically rampant caries of the anterior deciduous teeth results from the practice of allowing the infant or child to suck on a nursing bottle containing sweetened liquid for prolonged periods of time, particularly while sleeping (152-154). Mothers should be advised to avoid giving their infants a bottle of sweetened liquid or a sweetened pacifier, especially at bedtime.

Most individuals ingest sucrose several times a day as part of their diet, therefore it is virtually impossible for any one sucrose intake or type of sucrose intake to play a dominant role in the resulting caries increment. For this reason, experiments which find that once-daily use of sweetened breakfast cereal (155,156), or bananas or raisins or whatever, does not increase caries cannot be interpreted as evidence that the food in question is non-cariogenic. Their cariogenic potential could be determined more accurately using the IDT or modified ICT model in humans or by using the animal caries model.

Dietary Calcium to Phosphorus Ratio

Several years ago Stanton (157) concluded from epidemiologic data that dental caries was least when the calcium to phosphorus ratio in the diet was 0.56-0.66; caries increased when the ratio was higher or lower than optimum. A recent and more thorough epidemiologic study (158) found that the overall calcium to phosphorus ratio in the diet does not influence caries susceptibility. Nevertheless, it is possible that the high calcium and phosphate content in a few foods, such as milk and milk products, may be responsible for the low cariogenic potential of those foods (129,132).

Foods with Anticariogenic Potential

The sequence with which foods are eaten may influence their overall cariogenicity. Peanuts and Cheddar cheese consumed immediately after the ingestion of sucrose solution limit the fall in plaque pH that would normally occur after sucrose ingestion (159). When the indwelling electrode system is used, this effect can be observed even when the cheese (Cheddar, Monterey Jack, Swiss) is provided before the sucrose challenge (160,161). There is no doubt that the quantity of cheese chewed in these experiments would stimulate a copious flow of saliva and this alone might be responsible for the reduced pH response to sucrose (132,159). Recently cheese consumption by humans has been shown to reduce the ICT caries response to sucrose solution (132). Subsequent experiments with cheese extract have shown that cheese contains specific factors, including calcium and phosphate, which reduce the ICT cariogenicity of sucrose and are quite distinct from any beneficial effect of increased salivary flow caused by whole cheese (162). Thompson et al. (129) have noted that unsweetened and even sweetened milk have a lower ICT cariogenicity than one would expect from their sugar content; a similar mechanism may be operating here as in the case of the cheese extract. In vitro studies in several laboratories have suggested that other constituents in milk, cereals and snack foods may reduce the cariogenic potential of carbohydrate present in these foods (128,163,164).

Suitable Snacks

At the present time, a considerable number of foods can be identified as noncariogenic because their fermentable carbohydrate content (sugar and modified starch) is too low to cause a significant increase in plaque acidity (87,100,160,165,166). This category would include most of the staple dietary items such as red meats, poultry and fish of all types, vegetables, grains and nuts.

The present list of snacks which are safe for teeth offers a reasonable number of choices for individuals who wish to avoid extensive dental caries, but who cannot completely forego eating between meals (Table 5.1). Most of the items in this list are rich in nutrients as well as safe for teeth; some are also fairly high in fat. It is important to remember that snacks should contribute to, not detract from, a sensible diet.

It should be possible to expand this list considerably as more is learned about the influence of sugar concentration and modified starches in foods on their relative cariogenicity, and whether this cariogenicity is altered by other constituents or by the consistency of the foods.

Table 5.1 also includes a list of snack foods which can be used in moderation. Fresh fruit and unsweetened fruit juices provide important nutrients to the diet. However, they do contain some natural sugar (87), which would contribute to caries if consumed frequently between meals. Dried fruits contain up to 30 per cent sugar (87) and should not be consumed between meals. A number of popular starch-containing snacks are included in this category. They too should be used in moderation because they probably have some cariogenic potential (100,108) and because most are highly salted. Their frequent use might contribute to the development of hypertension.

Finally, there is much to commend the use of non-cariogenic foods, such as peanuts, cheese or sugarless gum, shortly after eating a sugar-containing food, since this will dramatically speed up the clearance of sugar from the mouth (110,160,167), and will reduce the amount of acid produced in plaque by the sugar-containing food (160,166,168).

Considering the importance of sugar in caries etiology, it is apparent that further studies on the cariogenic and anticariogenic potential of foodstuffs should be encouraged.

Alternative Sweeteners

The stimulus for industry to develop alternative sweetners to natural sugars comes from three main sources:

i) Public demand for sweetening agents which will have low caloric value;

ii) The need of diabetics for sweetening agents which are not metabolized to glucose;

TABLE 5.1

SNACKS WHICH ARE SAFE FOR THE TEETH

* Milk (homo, 2%, skim, or buttermilk)
* Tomato juice or vegetable cocktail
* Plain yogurt
* Raw fresh vegetables (carrots, celery, cauliflower, broccoli, zucchini, cucumber, green peppers)
* Sandwiches (ham, egg salad, tuna, salmon, cheese, meat spreads, peanut butter without jam or honey), hamburgers, hot dogs
* Crackers or melba toast with butter, cheese (any kind), peanut butter, tuna, shrimp
* Toast with butter, cheese, peanut butter
* Cheese
* Cottage cheese
* Boiled or devilled eggs
* Pizza
* Nuts (peanuts, cashews, etc.)
* Sunflower seeds
Popcorn, Plain or lightly buttered
Sugarless gum, sugarless lozenges
Coffee or tea without sugar (moderate amounts of artificial sweetener are acceptable)
Diet (sugar-free) soft drinks, soda water, or mineral water
Diet (sugar-free) gelatin desserts and toppings

SNACKS WHICH CAN BE USED IN MODERATION

* Unsweetened fruit juice
* Fresh fruits (apples, pears, oranges, grapes, peaches, bananas, berries)
** Potato chips, corn chips, wheat chips, "Nuts and Bolts", "Cheesies", pretzels

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* These snacks can also make an important nutritional contribution to the diet.

** These starch-containing snacks probably have low to moderate cariogenic potential.

iii) The potential market for beverages and other snack foods which are sweetened with a non-cariogenic sweetener.

The most effective answer to all three needs is provided by the low-calorie sweeteners since their intense sweetness (Table 5.2) allows them to provide satisfactory flavouring when used in minute amounts. Two synthetic sweetening agents of this type -- saccharin and cyclamate -- were used widely for many years. However, indications that both of these agents could produce undesirable side effects when fed in high doses to experimental animals (169,170) caused the Canadian government to prohibit their use by the food industry. They are now available only as table-top sweeteners.

Recently, another low-calorie sweetener -- Aspartame -- was approved by Health and Welfare Canada for use in beverages, chewing gum, lozenges, breakfast cereals, desserts and dessert toppings (171,172). It has gained rapid consumer acceptance in diet soft drinks and chewing gum. Although Aspartame is man-made, it is composed of two natural amino acids, aspartic acid and phenylalanine, joined together by a peptide bond and esterified with methanol (171). As such, it is readily hydrolyzed in the gut to its component amino acids and methanol which are absorbed and metabolized exactly like aspartic acid, phenylalanine and methanol derived from foods (171). The recommended Acceptable Daily Intake (ADI) of Aspartame of 40 mg/kg body weight (2.4 gm for a 60 kg person) would increase the average daily aspartic acid and phenylalanine intake by less than 12 per cent (171,173). Extensive studies in laboratory animals, including primates, showed no adverse effect from prolonged feeding of 4000 mg Aspartame per kg body weight per day -- this is 100 times the ADI (171). "Clinical tolerance studies in normal, obese, diabetic and phenylketonuric heterozygous adult humans showed no untoward effects associated with the consumption of Aspartame" (171). Nevertheless, food products containing Aspartame must carry a cautionary label to phenylketonurics and others who must restrict their dietary intake of phenylalanine.

Aspartame is unstable and loses its sweetness when exposed to the prolonged high heat used in baking or frying (171). Nevertheless, Aspartame could be effectively added to some cooked foods if this were done at the end of the cooking process.

Since Aspartame is 180-200 times sweeter than sugar, it can be used in concentrations of less than 0.5 per cent in foods and beverages. The ingestion of Aspartame in chewing gum or gelatin dessert does not produce a pH drop in dental plaque (174). Preliminary studies also indicate that Aspartame is non-cariogenic in rats (175).

However, low-calorie sweeteners replace only the sweetness of sugar. If Aspartame is used as the sweetener in food products, then some other ingredient(s) may have to be added to replace other qualities provided by sugar, such as bulk, texture, mouth-feel or crumb quality. From a dental standpoint, it is important that the food as a whole has low cariogenicity, not just the sweetener.

A different approach would be to use sugar alcohols in food products, such as confectionery, which require the characteristics contributed by high concentrations of sugar. The sugar alcohols have approximately the same sweetness as sugar (Table 5.2) and share many of the same physical properties. Of the three sugar alcohols now used in confectionery, two of them --mannitol and sorbitol -- are related to the common six-carbon sugars fructose and glucose. They are fermented by plaque microorganisms, particularly S. mutans, but so slowly that they cause only a slight drop in plaque pH(100,176). Further, the plaque organisms do not adapt to metabolize these sugar alcohols more rapidly even after months of sorbitol/mannitol intake (87, 176, 177). The cariogenicity of sorbitol/mannitol chewing gum used at least twice a day, has been evaluated in three randomized clinical trials of at least two years duration. In one trial the sugar alcohol gum was found to be significantly less cariogenic than a control sucrose gum (178). In the two other trials the group using sorbitol/mannitol gum at least twice a day had

TABLE 5.2

RELATIVE SWEETNESS OF SUGAR ALCOHOLS AND LOW-CALORIE SWEETENERS

Substance	Relative Sweetness*
Sucrose	1.00
Glucose	0.70
Fructose	1.70
Invert sugar (glucose + fructose)	1.20
Sugar Alcohols	
Sorbitol	0.54
Mannitol	0.57
Xylitol	1.00
Low-Calorie Sweeteners	
Ammoniated Glycyrrhizin	50
Sodium Cyclamate	30-80
Naringinin Dihydrochalone	100
Hesperidine Dihydrochalone	100
Aspartame	180-200
Saccharin	200-700

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*Sucrose is assigned a sweetness of 1 for comparison. Sweet taste depends on temperature, pH of medium used and on the sensitivity of the taster. (Adapted from Newbrun, 87).

no more caries than a control group which did not regularly chew gum (178, 179).

While sorbitol/mannitol is non-cariogenic when incorporated into a chewing gum, it may have a low level of cariogenicity when present in a vehicle which does not stimulate salivary flow (101). Such a low level of cariogenicity might be of importance in individuals who routinely use sorbitol/mannitol lozenges throughout the day (180). This point should be investigated using the ICT or IDT systems.

The third sugar alcohol -- xylitol -- is structurally related to the five-carbon sugar xylose. However, plaque bacteria lack the enzymes necessary to metabolize xylitol to organic acids (176,181). Hence, its use in humans does not cause any plaque pH drop even after months of use (176,182). Xylitol is completely non-cariogenic when evaluated in animals (144,183,184) or in humans using the ICT model (101). Thus, it is not surprising that complete substitution of sucrose by xylitol in foods, confections and beverages resulted in over 85 per cent reduction in DMFS increment, compared to the sucrose control group, over a two-year study period (98,184). It was unfortunate that the participants in this study were not randomly assigned to control and experimental groups. However, it seems unlikely that experimental bias. would produce differences in caries rates of the magnitude observed. The second clinical study of xylitol was only of one year's duration but it did include the random assignment of participants to the two chewing gum groups (184,185). The group which chewed 4-5 sticks of sucrose-containing gum per day had a DMFS increment of 3.76 while the other group which chewed 4-5 sticks of xylitol-containing gum per day had a DMFS increment of 0.33. The extremely low DMFS score for the xylitol group at the end of the study was surprising in view of the fact that both groups continued to consume their usual diet which contained sucrose. The authors attributed the low DMFS score to a therapeutic effect of xylitol. Attempts to prove the anticariogenicity of xylitol in animal studies have resulted in conflicting evidence (144,183, 186-189). However, there have been reports that xylitol can depress S. mutans counts in rats (188) and humans (190) and can reduce the ability of dental plaque or S. mutans to produce acid from sorbitol (191). It is clear that xylitol is the best sugar alcohol from the standpoint of non-cariogenicity.

One other property of sugar alcohols deserves mention. Sorbitol and mannitol are only partially absorbed from the intestine and cause gastrointestinal upset (diarrhea) in some individuals when more than 10 grams (150 mg/kg) is consumed per day (87). This suggests that sorbitol and mannitol should be reserved for use in snack items, such as chewing gum and lozenges, which are not consumed in large quantity per day. Xylitol is more completely absorbed and causes little or no gastrointestinal upset even at intakes of 50 grams per day (98). However, its use will likely be limited by its cost, which is almost ten times that of sucrose.

While there is no likelihood that sucrose will be totally replaced as a sweetening agent in the foreseeable future, the alternative sweeteners can increase the number of snack items that can be recommended as safe for teeth. Non-cariogenic sweeteners should also be used in medicinal tablets and syrups which must be ingested several times a day or just before sleeping (100,192).

5.6 DIETARY COUNSELLING IN DENTAL PRACTICE

Effectiveness of Counselling for Caries Prevention

The studies described in the previous section indicate that individual control of sugar intake can effectively decrease the risk of caries. The important question is whether or not members of the general population can voluntarily alter their sugar consumption pattern or their childrens' sufficiently to affect their caries susceptibility.

On theoretical grounds, the best target group for this approach should be the mothers of new-born children in whom dietary habits are not yet established. Human infants have an inborn preference for sweet rather than sour or bitter tastes (193) and will accept solutions which are much sweeter than mothers milk (194). In fact, infants will consume highly sweetened water (11 per cent sucrose) in preference to a normally sweetened milk formula with much better nutritive qualities (194). King (195) has shown that, normally, the sweet-eating pattern of the mother is soon passed to the infant.

Two studies in Sweden have tested the effect of preventive educational programs for new mothers on the subsequent caries experience of their children (196,197). Holst and Köhler (196) provided diet and oral hygiene counselling at six, 12 and 24 months of age and prescription of dietary fluoride supplements where necessary. They observed a 65 per cent lower caries experience at four years of age than in children whose mothers did not receive counselling (Table 5.3). If the preventive education was delayed until 24 months of age, the effectiveness was halved. Holm, et al.(197) found that a similar program provided at six, 12 and 36-48 months of age resulted in a 40 per cent decrease in caries rates. They attributed most of this caries reduction to dietary control, since the oral hygiene habits were not perceptively different and since the regular use of fluoride tablets throughout the study was observed in only 26 per cent of the participants. Multiple regression analysis showed that within the study group, there was a strong association between caries scores and the frequency of sugar ingestion.

The smaller caries reduction observed in the second study may be related to the timing of the third preventive counselling session. This came in the final year of the study and would probably not have any impact on the caries experience at four years of age. By contrast, the third counselling in the study of Holst and Köhler (196) came at 24 months of age, just when the deciduous dentition was being completed.

It is noteworthy that many health districts in Sweden have instituted preventive dental counselling of new mothers. While no data are given, it is likely that the saving in treatment cost to the dental health unit was sufficient to justify the cost of the counselling. It would be interesting to know if this preventive program is still cost-effective given the lower caries rates now seen in Sweden and elsewhere.

Unfortunately, most dental public health units in North America do not have an adequate budget to afford individualized counselling programs for new mothers even if the programs were cost-effective. Clinical studies should be carried out to determine whether preventive dental counselling of groups would be an effective and less costly alternative to individualized sessions. In the meantime, private dentists should ensure that new mothers are provided with, or referred for, preventive counselling on oral hygiene and dietary practices, including the use of fluoride supplements where necessary. According to the Swedish studies, this should be done when the child is six, 12 and 24 months of age (196,197). The results would probably be similar if the first counselling session occurred before the child's birth.

Individuals with severe caries problems constitute a second group for whom dietary analysis and counselling should always be carried out. Two studies conducted with such caries-susceptible individuals showed that dietary counselling with periodic reinforcement and caries activity monitoring could reduce caries increments by 60-88 per cent (198,199) (see Table 5.4). In the first study, even starch intake was restricted during the initial two weeks of the program. In the second study, only the restriction of between-meal consumption of sugar-containing beverages, foods and confections was advised.

Both studies stressed the need for reinforcement of dietary advice. In this respect, caries activity tests for highly acidogenic organisms (lactobacilli or S. mutans) served as a motivational aid and indicator of compliance with dietary recommendations (198,199). Although the results of these studies are encouraging, they must be verified and extended by additional studies with highly susceptible individuals.

Dietary counselling cannot be recommended as a routine procedure for all dental patients at the present time; there is simply too little information as to its cost-effectiveness to justify universal application. This is particularly true in areas where caries susceptibility is already reduced through water fluoridation and the use of fluoride dentifrices. As a priority, preventive counselling should be provided to women before or soon after their children's birth since the dietary pattern established in infancy tends to persist throughout life. For older children and adults, the decision to provide dietary counselling should be made on the basis of the individual's caries susceptibility. The dental profession should provide this service to individuals with high-caries susceptibility since it can have a major impact on the patient's need for future restorative treatment (198,199). Further research is required to substantiate the efficacy and cost effectiveness of dietary counselling to new mothers, mothers-to-be and high-risk individuals and groups.

Principles of Dietary Counselling in Dental Practice

The previous sections of this chapter have documented the essential role that systemic and local effects of diet play in the health of the dentition. In addition, there is reasonable experimental evidence that dietary counselling of patients can influence their food selection sufficiently to decrease their susceptibility to dental disease, and particularly to dental caries (196-199).

What aspects of dietary counselling are essential if it is to be effective? It should be clearly stated that counselling procedures have developed largely as a result of a trial and error process, from observation of human nature

TABLE 5.3

EFFECT OF PREVENTIVE COUNSELLING OF NEW MOTHERS ON SUBSEQUENT CARIES EXPERIENCE IN THEIR CHILDREN

		Subjects			%			
Investigators	**Age at Exam (Yrs.)**	**Birth Year**	**Counselling Age (Yrs.)**	**Number**	**Caries Free**	**Mean deft**	**Mean defs**	**Caries Red.** %**
Holst and Köhler (196)	4	1963	...	1313	26.4	4.6	...	...
	4	1965	2.0	696	42.0	3.2		30
	4	1967	.5, 1 & 2	688	62.6	1.6	...	65
Holm et al. (197)	4	1963	...	196	17.0	...	7.78	...
	4	1967	.5, 1 & 3-4	187	33.0	...	4.53	42

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* Oral hygiene advice plus dietary counselling, including prescription of dietary fluoride supplement where necessary

** Caries reduction as a per cent of pretreatment caries rates

TABLE 5.4

CARIES REDUCTION FOLLOWING DIETARY COUNSELLING OF HIGH-RISK INDIVIDUALS

Investigators	Subjects Age (Yrs.)	Subjects Number	Mean DMFS/Yr. Control	Mean DMFS/Yr. Counselled	Caries Reduction %	Comments
Becks (198)	8-60	790	10+*	1.2	88	Clinic patients
Krasse (199)	11-12	81	5.5	2.2	60	School children

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* Caries increment in year preceding counselling

and human response, rather than through formal experimentation. This does not detract from their effectiveness, nor does it deny that they may be further improved through formal experimentation.

The detailed procedures used in counselling have been described by a number of authorities in this field (12,200-207) and most comprehensively by Nizel (12,205), Palmer (206) and Snetselaar (207). The following points incorporate the essential features of good counselling:

1. The counselling arises from a practical problem which the patient is experiencing and is concerned about, e.g. extensive recurrent dental caries. If the patient is not interested in his/her dental problem, he/she will not be interested in its prevention. An adequate initial interview by the dentist or hygienist will bring out the patient's concerns for dental health and will also reveal important facts about the patient's lifestyle (206,208).

2. The patient must be involved in recording and examining his/her current dietary practices. Studies of nutrient intake indicate that a three- or four-day diet record (including one weekend day) can provide a reasonably accurate estimate of the usual diet (209-212); this can be repeated at least one week later if confirmation is desired. Involvement in this recording process generates interest in most patients, and makes them aware of their current dietary practices and more amenable to change (213).

3. The dietary record should be supplemented by careful interviewing to gain information on the usual frequency and duration of between-meal ingestion of sugar (and possibly starch)-containing items (214).

4. From the standpoint of dental caries, the analysis of the dietary record should center on the frequency, duration and distribution of sugar intakes throughout the day rather than on the total amount of sugar ingested (12,203). Therefore, a frequency check-off form, sectioned by time of day, is most appropriate. The check-off, or food-score approach can also be used to get a qualitative assessment of the diet compared to a national food guide (211,212, 215-217).

   If a quantitative assessment of the intake of individual nutrients is required, this can be calculated (211,212,215) by reference to standard food composition tables (218,219), taking portion size into account. A number of institutions now have computerized programs and data bases for doing the calculations. Some private practice nutritionists can provide computer analysis of dietary intake. The interpretation, to the patient, of the quantitative nutrient intake in comparison to Recommended Nutrient Intakes (RNI's or U.S. RDA's) is complicated (211,212,215) and should be done by a nutritionist.

Some health professionals have been attracted by questionable short-cuts to assessment of nutritional status, such as hair analysis. A leading authority on the biomedical use of hair analysis has cautioned that this technique is useless for assessment of vitamin status and very marginal with respect to mineral status (220). The same opinions were expressed in a statement by the Royal College of Physicians and Surgeons of Ontario (221).

5. The patient's adverse dietary practices must be related to the dental problem in simple but accurate terms by the health professional. Feedback through "open-ended" questioning is essential to ensure that the patient sees the dental problem to be a result of the dietary pattern (206,208).

6. The counsellor must assist the patient to reach recommendations for dietary change which will be compatible with his/her overall dietary practices and realistic in terms of demands for behavioural change (204). It is easier for the patient to substitute a non-cariogenic snack for a cariogenic one than to cease snacking altogether. In general, the patient is more likely to adhere to dietary modifications that he/she has suggested (222); and is more likely to remember them if they are written down.

7. The secondary objective of improving the nutritional quality of the patient's diet should not obscure the primary objective of the counselling, namely to alleviate a dental health problem. In the same spirit, it should be considered unethical for health professionals to use a dental health situation as a vehicle for promoting trendy but unproven nutritional advice.

8. Where dietary counselling (or other preventive service) is provided by a dental hygienist or nutritionist, it is essential that the dentist conveys the importance of these procedures to the patient in advance and shows a continuing interest in this aspect of his/her treatment plan. Such reinforcement does not require an extensive recall appointment; brief but effective discussion of the patient's dietary modification to date can take place during treatment appointments.

9. Although the supporting research evidence is not strong, caries susceptibility tests and, possibly, audiovisual materials may play a useful supportive role in motivating some patients to modify their dietary practices. However, these tests and materials are not a substitute for the essential procedures outlined above.

Dental professionals interested in counselling will benefit from the more thorough treatment of the subject that is provided in several books and articles (12, 202-208). Several interesting articles are available on food selection and dietary modification (216, 223-226). Finally, attention should be drawn to the excellent issue of the Journal dentaire du Québec which was devoted to diet and dental health (227).

Caries Susceptibility Tests

The contemporary decrease in caries rates has created the situation wherein the majority of the population has relatively little caries while a minority of the population (about 20 per cent) has a serious caries problem (76). The new challenge to the dental profession is to recognize the high-risk cases before their dentition is ruined. In this regard, currently available caries susceptibility tests, while not perfect, can identify many of these high-risk individuals (228-231). Simple tests for salivary lactobacilli, (232,233) S. mutans (234-236) and buffer capacity (237-238) are now available for use in the dental office. Krasse (180), Larmas (239), and Nikiforuk (240) have described the use of these tests for identifying high-risk individuals and for monitoring their response after preventive counselling or preventive therapy directed against cariogenic organisms.

5.7 RECOMMENDATIONS

1. Information on the importance of nutrition in the formation and maintenance of a healthy dentition should be taught in the school system as an integral part of a child's health education. Government and professional organizations can play a valuable role in helping to provide high quality audiovisual and other materials for classroom use. One such teacher's guide is available from the Department of National Health and Welfare (241) and others may be available from provincial Departments of Health.

2. Dental patients should be informed about the key role of dietary sugars in caries causation and of the supportive role of a sensible diet in maintaining periodontal health. The information on dental caries should stress the need to reduce the frequency and duration of sugar intake and recommend the substitution of non-cariogenic food items.

3. New mothers should be counselled on dental health aspects of infant feeding when their children are six, 12 and 24 months of age. For some women it may be more convenient to have the first counselling before the child's birth. Particular attention should be drawn to the problem of nursing-bottle caries and to the need for early establishment of sensible eating habits. This counselling could be done in conjunction with a prenatal or well-baby clinic or in a private practice setting. The effectiveness of group sessions for preventive dental counselling should be explored.

4. Individuals who show a high risk of developing dental caries or periodontal disease should be given a dietary evaluation to determine if nutritional inadequacy might be a significant factor in their dental problem. If so, they should be counselled to identify dietary modifications which they could make to decrease their risk.

5. While dentists could do preventive dental counselling of patients, the majority of this service can be effectively provided by dental hygienists or by nutritionists who have a dental orientation.

6. The counselling procedure should actively involve the patient in analyzing his diet and in formulating modifications to improve dental health primarily, and general health secondarily. These changes should achieve the dental health objectives with minimal disruption to the patient's lifestyle. The patient's progress in dietary modification should be reviewed at subsequent treatment appointments in order to reinforce his/her efforts for change.

7. Caries susceptibility tests in the form of salivary S. mutans or lactobacillus counts may provide a useful educational and motivational tool for

caries-prone individuals, particularly when used to monitor compliance with dietary recommendations.

5.8 SUGGESTIONS FOR FURTHER RESEARCH

1. Further research is required to establish the degree to which gingivitis and periodontal disease can be aggravated by chronic, low intake of vitamin C, folic acid, calcium, zinc or iron and can be lessened by supplementation with the appropriate nutrient(s). The initial and final nutrient status of the individuals should be established by quantitative assessment of nutrient intake and appropriate biochemical tests.

2. There should be additional investigations into whether or not supplements of vitamin C given prophylactically before extensive subgingival scaling or periodontal surgery will improve tissue recovery or repair.

3. Research is needed to identify what benefits accrue, in caries prevention, from the pre-eruptive, systemic exposure to fluoride in a society which is almost universally and daily exposed to topical fluoride in the form of fluoride dentifrice.

4. A comprehensive investigation should be carried out to determine the best way of identifying individuals with high risk of developing caries. A wide range of dental, salivary, plaque, dietary and socioeconomic factors should be evaluated to determine the best minimal combination(s) of these factors for caries prediction.

5. The cariogenicity of sugars and modified starches should be reappraised with respect to both coronal caries in children and root caries in adults. The study populations should include a high proportion of individuals with medium- to high-caries susceptibility.

6. The effectiveness of preventive dental counselling to high-risk groups should be investigated further, with particular emphasis on time and cost factors in relation to benefits. Group counselling should be explored first in terms of operational practicality and then in terms of effectiveness.

7. There should be more research on foods with anticariogenic potential, such as cheese, in order to identify the constituents responsible and their mode of action. The efficacy of incorporating these constituents into model snack foods or remineralizing preparations could then be tested.

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CHAPTER 6

CHAPTER 6

FLUORIDES

L.W. Ripa

6.1 INTRODUCTION

Many methods which use fluoride to inhibit dental decay are available. These methods employ different fluoride compounds, a wide range of fluoride concentrations, and a variety of vehicles, application techniques, and treatment frequencies. A basic understanding of the field of fluoride therapy is necessary in order to make knowledgeable decisions concerning the implementation of community preventive programs and to provide appropriate preventive therapy for individuals patients.

Table 6.1 lists the fluoride concentrations of commonly used fluoride products and the amount of fluoride used for single administrations of these products (1). Systemic supplements, which are meant to be swallowed, have the lowest fluoride concentration and provide the smallest individual dose of fluoride, not to exceed 1 mg/day. Topical fluoride products used by the patient, usually at home or in school, have an intermediate fluoride concentration and exposure. Products for professional administration have the highest fluoride concentration and the largest amount of fluoride used for a single treatment.

6.2 WATER FLUORIDATION

Fluoride in drinking water at appropriate concentrations safely helps to inhibit dental caries. The most common method of fluoridation involves adjusting the concentration of fluoride in a community's water supply, and community water fluoridation is the most important public health method of caries prevention in the world. Community water fluoridation depends upon the availability of piped water supplies. In rural areas where there are no piped community water systems, a school which has its own well may have its water individually fluoridated.

Community Water Fluoridation

Three independent studies were initiated in 1945 in which the level of fluoride in the communities' water supplies was adjusted to 1.0 part per million (ppm). Each fluoride-adjusted community was paired with a similar community which was fluoride-deficient and served as a control. The two American investigations were known as the Grand Rapids-Muskegon Study (2) and the Newburgh-Kingston Study (3), while the Canadian experiment was known as the Brantford-Sarnia-Stratford Study (4). The Canadian study was particularly well designed in that along with the experimental city of Brantford and the control city of Sarnia, Stratford, a naturally fluoridated community (1.6 ppm), was included as the active control.

Table 6.2 presents the results of these and other studies of community water fluoridation (3, 5-9). In all of the communities listed, the caries inhibition to the permanent teeth of school-aged children was approximately 50 per cent, despite the fairly wide difference in tooth decay rates [see review 10].

Effects of Community Water Fluoridation on Adults

Although the benefits of community water fluoridation have been generally associated with children, adults with a lifelong exposure to fluoridated water have less dental caries than those who reside in fluoride-deficient communities. Englander and Wallace compared the caries prevalence of young adults (18 and 19 years old) reared in optimally fluoridated or fluoride-deficient communities (11). They found aproximately 60 per cent fewer DMF surfaces in those with a residential history of consuming fluoridated water. Russell and Elvove compared the caries experience of 20- to 44-year-old residents of Colorado Springs, Colorado (2.5 ppm F) and Boulder, Colorado (0.1 ppm F)(12).

TABLE 6.1
CONCENTRATION OF FLUORIDE IN COMMON FLUORIDE METHODS AND AMOUNT OF FLUORIDE EXPOSURE

	Fluoride	Fluoride Concentration		Fluoride Exposure	
Method	Source	ppm F	% or Amount F	Usual Amount Used	mg F
Systemic Treatment					
Community Water Fluoridation	NaF Sodium Silicofluoride Hydrofluosilicic Acid	1	0.0001%	1 litre/day	1.0
Drops	NaF		0.125 mg F/drop	2 drops	0.25
			0.25 mg F/drop	1-2 drops	0.25-0.5
			0.5 mg F/drop	1-2 drops	0.5-1.0
F-Vitamin Drops	NaF		0.25 mg F/drop	1-2 drops	0.25-0.5
			0.5 mg F/drop	1-2 drops	0.5-1.0
Tablets and Lozenges	NaF or APF		0.25 mg F/tablet	1 tablet	0.25
			0.5 mg F/tablet	1 tablet	0.5
			1.0 mg F/tablet	1 tablet	1.0
F-Vitamin Tablets	NaF		0.5 mg F/tablet	1 tablet	0.5
			1.0 mg F/tablet	1 tablet	1.0
Oral Rinse Supplements	NaF or APF	200-230	0.02%	5 ml	1.0
Self-applied Topical Treatment (Home/School Use)					
Mouthrinses	0.22% NaF	100	0.01%	2x5 ml	1.0
Twice Daily	0.44% APF	200	0.02%	5 ml	1.0
Daily	0.05% NaF	230	0.02%	5-10 ml	1.0-2.0
Weekly	0.2% NaF	900	0.09%	5-10 ml	4.5-9.0
Dentifrices	0.76% Na_2PO_3F	1000	0.1%	1 gm	1.0
	0.24% NaF	1100	0.11%	1 gm	1.1
	0.1% NaF + 0.76% Na_2PO_3F	1455	0.15%	1 gm	1.5
Gels					
Brushed	0.4% SnF_2	1000	0.1%	1 ml	1.0
Brushed	1.1% NaF or APF	5000	0.5%	1 ml	5.0
Trays	1.1% NaF or APF	5000	0.5%	5 ml	25.0
Operator - applied Topical Treatment (Office Use)					
Solution	2% NaF	9040	0.9%	5 ml	45.0
	8% SnF_2	19360	1.9%	5 ml	95.0
	APF	12300	1.2%	5 ml	62.0
Gel	APF	12300	1.2%	5 ml	62.0
Varnish	NaF	22600	2.3%	0.5 ml	11.0
	Difluorosilane	7000	0.7%	0.5 ml	3.5

TABLE 6.2

CARIES EXPERIENCE BEFORE AND AFTER THE INTRODUCTION OF CONTROLLED COMMUNITY WATER FLUORIDATION

Community	Age (years)	DMFT		Per cent Caries Reduction
		Before F	After F	
Brantford, Ontario(5)*	8	2.4	1.1	54.2
Newburgh, New York(3)	9	3.1	1.5	51.6
Grand Rapids, Michigan(6)	10	4.9	2.3	53.1
Hastings, New Zealand(7)	11	7.2	3.6	50.0
Evanston, Illinois(8)	12-14	9.0	4.6	48.9
Harlepool, England(9)	15	9.0	5.0	44.6

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*These numbers in this and other tables in this chapter correspond to reference numbers in the bibliography.

In reporting both the age-specific mean DMFT index (Figure 6.1) as well as the mean number of missing teeth (Figure 6.2), the considerable benefit of fluoridated water to adult dental health was very evident.

The only studies of the effects of fluoridated water on root caries in adults were conducted by Banting and Stamm (13). They found that the mean concentration of fluoride in the root surfaces of extracted teeth from Stratford, Ontario adults (F = 1.6 ppm) was higher than that of teeth obtained from Chatham, Ontario adults (F = 0.1 ppm) (13). In comparing the root caries prevalence of approximately 500 lifelong adult residents of Stratford (mean age 40.2 years) with that of lifelong residents of fluoride-deficient Woodstock (mean age 42.8 years), these same investigators found 53 per cent less root caries in residents of the fluoridated community (14).

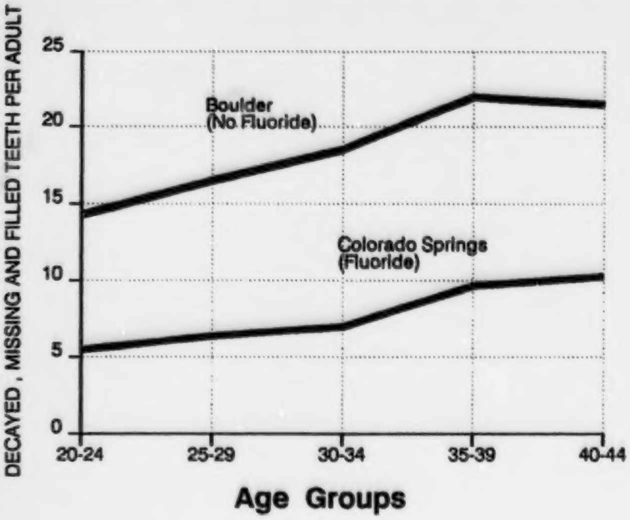
Additional data on the effect of optimally fluoridated water on adult dental health have been reported in a World Health Organization monograph (15) and in the book by Murray and Rugg-Gunn (10).

Technical Considerations of Community Water Fluoridation

The optimal fluoride ion concentration range for community water fluoridation is 0.7 to 1.2 parts per million (ppm). Higher fluoride concentrations are associated with lower dental caries prevalence levels but both the frequency and severity of enamel fluorosis increases to undesirable levels (16). The stated range of 0.7 to 1.2 ppm F does not reflect a lack of scientific specificity, but rather takes into account that the mean annual temperatures in different climatic zones result in different fluid consumption patterns (17). The higher the

Figure 6.1

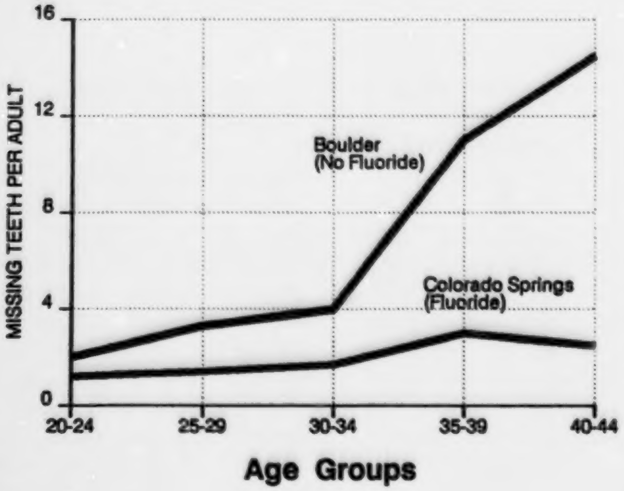
DECAYED, MISSING AND FILLED TEETH PER ADULT: FLUORIDE AND FLUORIDE-DEFICIENT COMMUNITIES



Source (12)

Figure 6.2

MISSING TEETH PER ADULT: FLUORIDE AND FLUORIDE-DEFICIENT COMMUNITIES



Source (12)

mean annual temperature, the more the average volume of water consumed and the lower the optimal water fluoride concentration. Standards have been developed for optimal water fluoride levels in relation to mean annual temperature (18) (Table 6.3). Federal government guidelines recommend that the fluoride concentration in publicly distributed water supplies not exceed 1.5 ppm in order to minimize the risk of enamel fluorosis.

Community Water Fluoridation Worldwide

It is difficult to determine the actual number of people who are consuming water containing naturally occurring or adjusted optimum levels of fluoride. In 1984, the Canadian Dental Association estimated that there were 248 million worldwide users, half of whom, about 123 million, were residents of the United States (19). Based upon the percentage of citizens consuming fluoridated water, Australia and Ireland rank first and second, with two-thirds and three-fifths of their populations on fluoridated systems. Slightly more than half of the United States population is drinking fluoridated water, more than 37 per cent of Canadians, and more than 12 per cent of the population of Great Britain.

The last collated data for Canada listed the fluoridation status for Canadians as of December 1976 (20). At that time, 8.5 million Canadians were served by fluoridated water, which represented 37 per cent of the population and 46 per cent of those serviced by piped water systems (Table 6.4). Since then, the Quebec metropolitan area has been fluoridated, adding 576 000 people to the fluoridation rolls.

The benefits of fluoridation to Canadians were documented by Lewis (21). In a report prepared for the city of Toronto Health Department, he compared the dental status of seven-, nine- and eleven-year-old children for 1963, the year in which Toronto was fluoridated, and for 1970 and 1975. By 1975, when all of the children surveyed had used fluoridated water all their lives, there was a 42 per cent decrease in the number of decayed, missing, and filled permanent teeth and an approximate doubling of the number of children caries-free in their primary and permanent dentitions (Table 6.5).

The Canadian Dental Association, in 1981, expressed its concern about the poor utilization of fluoridation as a dental public health method in Canada (22). In the same year, the Canadian Dental Association published a manual, prepared by Clark, that described strategies for fluoridation initiatives and implementation (23).

Objections to Community Water Fluoridation

The major arguments of those opposed to fluoridation are:

1. fluoridation is ineffective against dental caries;

2. fluoride is biologically harmful; and

3. community fluoridation deprives citizens of their rights to make a free choice about accepting medication.

The value of community water fluoridation in inhibiting caries has already been addressed in this chapter. The "individual rights" issue has been struck down repeatedly by North American courts whose rulings have upheld the legality of community programs that promote the general welfare of the majority of citizens.

The most recent biological accusation against fluoride is an alleged relationship between water fluoridation and cancer (24-27). The reports purporting to link fluoridated water with increased cancer incidence were prepared by Yiamouyiannis and Burk for the National Health Federation, an organization long opposed to fluoridation but supportive of such therapies as laetrile. Their conclusions have been rejected by reviews of their work and by independent studies conducted in Canada (28) and England (29) and in the United States (30-32). Hoover and co-workers studied cancer mortality and incidence in specific localities of the United States between 1950 and 1969 and reported no trend that could be attributable to fluoridation (30). Doll and Kinlen reviewed cancer mortality rates in ten fluoridated cities and ten fluoride-deficient cities in the United States for

TABLE 6.3

AIR TEMPERATURE AND WATER FLUORIDE LEVELS

Annual Average of Maximum Daily Air Temperatures**		Recommended Control Limits - Fluoride Concentration in mg/L*		
		Lower	Optimum	Upper
C.	F.			
10 - 12.05	50.0 - 53.7	0.9	1.2	1.7
12 - 14.6	53.8 - 58.3	0.8	1.1	1.5
14.6 - 17.6	58.4 - 63.8	0.8	1.0	1.3
17.7 - 21.4	63.9 - 70.6	0.7	0.9	1.2
21.5 - 26.2	70.7 - 79.2	0.7	0.8	1.0
26.2 - 32.5	79.3 - 90.5	0.6	0.7	0.8

* Milligrams per litre (mg/L) equals parts per million (ppm).

** Based on F. temperature data obtained for a maximum of five years.

Source: (18)

TABLE 6.4

FLUORIDATION IN CANADA BOTH ADJUSTED AND NATURALLY OCCURRING SHOWN BY PROVINCE, DECEMBER 31, 1976

Province or Territory	Systems Supplying Fluoride	Population Served	Expressed as % of Total Population	Expressed as % of Population on Potable Water Systems
NEWFOUNDLAND	4	52 335	9.3	16.1
PRINCE EDWARD ISLAND	2	20 843	17.6	48.4
NOVA SCOTIA	22	332 155	40.0	70.6
NEW BRUNSWICK	5	88 691	13.1	24.9
QUEBEC	43	777 366**	12.3	14.4
ONTARIO	122	5 155 381	62.3	72.3
MANITOBA	48	667 912	65.3	84.1
SASKATCHEWAN	113	333 496	36.2	58.2
ALBERTA	93	817 004	44.4	59.5
BRITISH COLUMBIA	27	287 099	11.6	14.5
YUKON TERRITORY	2	11 800	54.0	78.6
NORTHWEST TERRITORIES	6	18 472	43.3	73.8
CANADA	487	8 557 554*	37.2	46.4

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* Of this total, 174 181 received naturally occurring fluoride (less than 1%)

** In 1978, Metropolitan Quebec was fluoridated adding 576 000 people to those consuming fluoridated water

Source: (20)

TABLE 6.5

DENTAL STATUS OF CHILDREN BORN IN METROPOLITAN TORONTO: SURVEYS CONDUCTED IN 1963, 1970 AND 1975

	Age Group (Years)	1963*	1970	1975
Missing Primary Teeth (% children)	7	48.1	37.1	19.1
	9	57.7	45.6	18.8
Missing Permanent Teeth (% children)	7	2.1	0.8	0.0
	9	10.0	5.8	1.5
Caries Free Primary Teeth (% children)	7	13.5	26.6	39.1
	9	14.2	16.9	32.4
Caries Free Permanent Teeth (% children)	7	62.7	75.3	78.9
	9	28.7	42.7	55.8
	11	14.6	21.6	26.2
def Teeth (mean)	7	5.3	3.5	2.5
	9	4.8	4.2	2.4
DMF Teeth (mean)	7	5.3	3.5	2.5
	9	2.1	1.4	1.1
	11	3.6	2.7	2.3
Sample Size	7	1,072	913	575
	9	1,001	886	547
	11	923	723	545

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* 1963 data not limited to Toronto-born children since birth place was not categorized in surveys until 1964.

Source: (21)

1950 to 1970 (33). After adjusting for age, sex, and ethnicity, they found a decrease in cancer rates in cities with fluoridated water, while there was no change in fluoride-deficient cities. In an extensive review of mortality trends from 1950 to 1970 in 473 United States cities, Rogot and co-workers also failed to document a relationship between the fluoride levels of the drinking water and either heart or cancer death rate trends (31). Lang and Clark have reviewed the various allegations concerning health risks of fluoridation for the Canadian Dental Association (34), and found them invalid.

School Water Fluoridation

Not all people live in communities that receive piped water. Thus, even if all community water supplies were eventually fluoridated, all of the people would not be served. A method which is directed exclusively at school children is the fluoridation of individual school water systems. School fluoridation is indicated for rural schools with their own wells in which the students (age six years and older) drink fluoride-deficient water at home (0.3 ppm F or less).

Four studies which investigated the effects of school water fluoridation have been reported. In the first study, in the Virgin Islands, the water supply of two schools was fluoridated at 2.3 ppm F, slightly more than three times the optimal level.

Eight years later, children drinking the fluoridated water had a 22 per cent lower DMFT score compared to counterparts in control schools with unadjusted water supplies (35).

The next two studies were conducted in Pike County, Kentucky and Elk Lake, Pennsylvania (36). Pike County schools were fluoridated at 3.0 ppm, or 3.3 times the optimum level recommended for community water supplies in that temperature zone, and Elk Lake schools were fluoridated at 5 ppm, or 4.5 times the optimum. In both studies, children in the fluoridated schools received caries examinations before fluoride was added to the water supplies. The results of these examinations served as the baseline level of caries. After eight years, there was a decrease in caries (DMFT) prevalence of 33 per cent and 35 per cent for the Pike County and Elk Lake children, respectively (37). The Pike County study was discontinued after eight years. The children in the Elk Lake program, examined 12 years after the institution of fluoridation, had a decrease in their DMFT prevalence of 39 per cent (36-38).

The fourth school water fluoridation study was in Seagrove, North Carolina. The Seagrove study, by fluoridating at 6.3 ppm (seven times the optimal level) was implemented to determine the most effective water fluoride concentration for school fluoridation programs. After 12 years, the DMFT prevalence reduction was 48 per cent (39). This was similar to the reduction in caries experience found for Elk Lake, in which the level of fluoridation was 4.5 times optimal. Because the higher fluoride concentration possessed no clear-cut superiority in effectiveness, the investigators supported fluoridating school water supplies at 4.5 times the optimal indicated for a region (39).

When the homes of individual pupils receive different levels of water-borne fluoride, concern has been expressed that the children who have access to water containing more than minimal amounts of fluoride may develop fluorosis from using both fluoride-containing water sources. Rozier and Dudney, however, have shown that this is not a problem (40). These investigators checked for enamel fluorosis in children who were participating in a school water fluoridation program in which the level of fluoridation was 5.6 times optimal. The drinking water in the children's homes varied from less than 0.1 ppm to greater than 6.0 ppm. Only those children whose home drinking water contained 2.0 ppm F or more had objectionable fluorosis. The fluoride in the school's water was not a factor in these findings. The observations of Rozier and Dudney support the conclusions of the several school water fluoridation studies that school-age children (approximately age six and older) are not at risk to fluorosis.

6.3 FLUORIDE SUPPLEMENTS

Dietary fluoride supplements include fluoride-containing vitamins, fluoride drops and tablets and oral rinse supplements. Those supplements where the amount of fluoride that would be consumed in the maximum daily dose recommended exceeds 1 mg would require a prescription. They may be used either by individual patients or by participants of a school- or home-based public health preventive dentistry program.

Fluoride supplements are ingested and promote the caries resistance of teeth by the pre-eruptive deposition of fluoride into enamel. Nevertheless, a number of clinical studies have reported that fluoride supplements also provide caries protection to teeth that are already erupted. It is important to remember, therefore, that when selecting a fluoride supplement for an individual or community program, the anticaries benefits will be maximized by choosing a preparation that provides both systemic contact to teeth that are unerupted and topical contact to teeth that are erupted.

Results of Fluoride Supplement Clinical Trials

There have been about five dozen clinical reports on the effectiveness of daily fluoride supplements. Most of these articles have been cited in several recent extensive reviews of the subject (41-44). Only English language reports appearing since 1970 are listed in Tables 6.6, 6.7 and 6.8.

The effect of neutral sodium fluoride supplements on the primary teeth is presented in Table 6.6 (45-53). The caries reductions listed exhibit a wide range. Nevertheless, the fact that the results of the majority of studies are positive, with most caries reductions being greater than 40 per cent and some more than 60 per cent, indicate that a consistently high result can be expected with this method of caries prevention.

An important variable is the initial age of participating subjects. As reviewed by Mellberg and Ripa (44), and seen in the studies by Margolis, et al.(46) and Granath, et al.(53), listed in Table 6.6, the greater caries reductions occurred in those children in whom supplementation was begun early (at or shorthly after birth). Supplementation beginning at age three or four is generally less effective in inhibiting caries in the primary dentition. This suggests that the mechanism whereby fluoride supplements prevent caries in the primary teeth is enhanced by pre-eruptive or early post-eruptive fluoride contact.

The effect of neutral sodium fluoride supplements on the permanent teeth is presented in Table 6.7 (46,48,49,52, 54-56). Although the results show a wide variation, they are consistently favourable and the impression of the composite finding is that fluoride supplements are an effective means of inhibiting caries in the permanent dentition. As with the primary teeth, it is important to begin supplementation early. In the trial by Margolis et al., the results of which are shown in Table 6.7, children taking fluoride supplements from birth had a 51 per cent DMFT reduction compared to the 20 per cent reduction for children who began fluoride supplementation when they were four years old (46).

Table 6.8 lists clinical trials with acidulated phosphate fluoride (APF) supplements (54, 57-59). (The study by DePaola and Lax, which was published before 1970, is included for completeness [58]). Both tablets and oral rinse supplements were used in these trials. The tablets were chewed, swished and swallowed in order to achieve topical as well as systemic contact with the teeth. Since all of these studies were conducted in schools, the children were six years or older when they began participation; therefore, the systemic effect would be expected to be minimal. Nevertheless, teeth that erupted during the study (58) or late erupting teeth (57,59) received about twice as much caries protection as teeth that were present in the mouth before the study began. A comparison of the results presented in Tables 6.8 and 6.7 shows that, for similarly aged children, there is no special benefit from using acidulated, rather than neutral, fluoride supplements.

Prenatal Fluoride Supplements

A recurring question is the effectiveness of prenatal fluoride supplements in inhibiting caries in the primary teeth. Contrary to earlier beliefs, fluoride does pass the placenta and becomes incorporated into foetal bones and teeth (60-64). It is believed that supplemental fluoride exerts its maximum cariostatic effect if ingested during the mineralization of the surface of the crowns. In primary teeth, this process is mostly postnatal; hence, benefits from prenatal ingestion of fluoride would be minimal.

In 1966, the United States Food and Drug Administration stated that sufficient evidence was lacking to support claims of efficacy of prenatal fluoride supplements, although their safety was not in question (65). The Food and Drug Administration banned advertising claiming that prenatal fluoride supplements provided a dental benefit, but it did not ban their sale by prescription. In 1981, the proceedings of a symposium on the effectiveness of prenatal fluoride supplements was reported in the Journal of Dentistry for Children (66-71). The conclusion of Driscoll, who reviewed the relevant clinical trials, was that, "despite

TABLE 6.6
CARIES-PREVENTIVE EFFECTS OF NEUTRAL SODIUM FLUORIDE SUPPLEMENTS ON PRIMARY TEETH

Study	Daily Dose (mg F)	Approx. Age Supplementation Began (Yrs.)	Study Duration (Yrs.)	Percent Reduction		Baseline defs		defs or deft Increment		Saved per yr.	Final Sample Size	
				deft	defs	Control	Treated	Control	Treated		Control	Treated
Margolis et al.(46)	0.5-1.0 + V	B	4-6	67		0	0	2.17	0.72	0.29 (t)	355	295
(1975)	1.0 + V	4	2	45		?	?	2.17^{a}	1.20^{a}	N.A.	355	271
Hamberg(47)	0.5 + V	B	3	57		0	0	1.4	0.6	0.27(t)		
(1971)			4	54		0	0	3.4	1.6	0.45(t)		
			5	50		0	0	4.4	2.2	0.44(t)	363	342
			6	49		0	0	5.2	2.7	0.42(t)		
Aasenden & Peebles(48) (1974)	0.5-1.0 + V	b	7-12	73		0	0	6.52^{b}	1.43^{b}	0.52(t)	78	87
Hennon et al.(49) (1970)	0.5-1.0 + V	B-5.5	5.5	49	56	0	0	17.28^{a}	7.56^{a}	1.76(s)	36	46
Fanning et al.(50)	?	<1	3-4	53		0	0	1.37	0.58	0.22(t)	90	182
(1975)			4-5	34		0	0	2.12	1.40	0.16(t)	1036	1586
			5-6	33		0	0	2.75	1.85	0.16(t)	581	801
Hennon et al.(51)	0.5-1.0 + V^{d}	<1	3.5^{c}	33	30	0	0	3.88	2.73	0.32(s)	52	52
(1977)	0.5 + V^{d}	<1	3.5^{c}	39	31	0	0	3.88	2.69	0.34(s)	52	52
Hennon et al.(45)	1.0 + V	1.5-3	2	60	66	0.51	1.95	6.93	2.39	2.17(s)	96	95
(1972)	1.0	1.5-3	2	55	63	0.51	1.03	6.93	2.59	2.17(s)	96	91
Anderson & Grahnen(52) (1976)	0.25-0.5	<1	4-5^{e}	26	31	0	0	8.50	5.83	0.59(s)	119	125
Granath et al.(53)	0.25-0.5	<2	2-4		82 BL	?	?	2.29	0.40	0.63(s)	344	48
(1978)					68 MD	?	?	4.19	1.35	0.94(s)		
	0.25-0.5	2-3	1-2		39 BL	?	?	2.29	1.39	0.60(s)	344	123
					25 MD	?	?	4.19	3.14	0.70(s)		

V = Vitamins BL = buccolingual MD = mesiodistal

a. prevalence data from birth

b. for primary cuspids and molars

c. study duration up to 6.5 years; however, 3.5 year group had the most participants

d. water F conc = 0.6 - 0.8 ppm

e. children received F tablets for 4-5 yrs from approx. 1 yr old but were examined at ages 8-10 yrs.

TABLE 6.7

CARIES-PREVENTIVE EFFECTS OF NEUTRAL SODIUM FLUORIDE SUPPLEMENTS ON PERMANENT TEETH

Study	Daily Dose (mg F)	Approx. Age Supplementation Began (Yrs.)	Study Duration (Yrs.)	Per cent Reduction		Baseline defs		defs or deft Increment		Saved	Final Sample Size	
				DMFT	DMFS	Control	Treated	Control	Treated	per yr.	Control	Treated
Aasenden & Peebles(46) (1974)	0.5-1.0 + V	B	7-12		80	0	0	7.93	1.57	0.67	93	100
Hennon et al.(49) (1970)	0.5-1.0 + V	B-5.5	5.5	52	64	0	0	4.81	1.71	0.56	31	39
Margolis et al.(46) (1975)	0.5-1.0 + V	B	10	51		0	0	1.83	0.88	0.09(t)	158	84
	1.0 + V	4	6	20		0	0	1.83	1.46	0.06(t)	158	213
Andersson & Grahnen(52) (1976)	0.25-0.5	1	$4\text{-}5^b$	42	40	0	0	3.89	2.34	0.34	119	125
Allmark et al.(56) (1982)	1.0	6	6	59	61	0^a	0^a	3.29	1.28	0.34	70	124
Stephen & Campbell(55) (1978)	1.0	5.5	3		49	$?^d$	$?^d$	5.96	3.02	0.98	48	54
Aasenden et al.(54) (1972)	1.0^c	8-11	3	26	27	7.99	8.53	12.29	8.98	1.10	139	114

V - Vitamins

a. baseline deft was 4.31 for control group and 4.30 for treated group

b. children received F tablets for 4-5 yrs from approx 1 yr old but were examined at ages 8-10 yrs.

c. as a rinse; all others drops and/or tablets

d. participants stratified at baseline to def index

TABLE 6.8
CARIES-PREVENTIVE EFFECTS OF ACIDULATED PHOSPHATE FLUORIDE SUPPLEMENTS ON PERMANENT TEETH

Study	Daily Dose Dose (mg F)	Approx. Age Supplementation Began (Yrs.)	Study Duration (Yrs.)	Percent Reduction		Baseline defs		defs or deft Increment			Final Sample Size	
				DMFT	DMFS	Control	Treated	Control	Treated	Saved per yr.	Control	Treated
DePaola & Lax(58) (1968)	1.0	6-8	2	23	20	3.90	4.45	4.48	3.60	0.44	136	130
Driscoll et al.(57)	1.0	6-7	6		28	1.42	1.63	7.25	5.22	0.34	153	150
(1978)	2.0	6-7	6		29	1.42	0.82	7.25	5.14	0.35	153	135
Driscoll et al.(59)	1.0	6-7	9.5^b		26	1.24	1.57	14.45	10.75	0.62^c	112	93
(1981)	2.0	6-7	9.5^b		28	1.24	0.82	14.45	10.41	0.39^d	112	95
Aasenden et al.(54)	1.0^a	8-11	3	3?	30	7.99	7.32	12.29	8.66	1.21	139	109

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a. as an APF rinse; all others APF tablets
b. 6 yrs of F tablets plus 3.5 yrs posttreatment
c. average surfaces saved per year based on 6 yr treatment period
d. average surfaces saved per year based on 6 yr treatment period plus 3.5 yrs posttreatment

encouraging trends in existing data, administration of dietary fluoride supplements to pregnant women cannot be recommended at this time, because conclusive clinical evidence that the procedure reduces dental caries in the teeth of offspring is lacking" (67). Thus, until more definitive clinical evidence is available, the two-decade-old ruling of the United States Food and Drug Administration still should be regarded as authoritative.

Dosage and Administration of Fluoride Supplements

The current accepted fluoride dose schedule is listed in Table 6.9 (72,73). In order to properly prescribe fluoride supplements, it is necessary to know the child's age (age serving as an approximate guide to body weight) and the fluoride level in the water supply. The municipal water authority supplying piped water to a community can provide the water fluoride concentration. However, if the patient's home has a water conditioner, the fluoride concentration of the water in the home should be confirmed since in one study water softeners reduced the water fluoride concentration by an average of 23 per cent (74), whereas, in another study, they had no effect (75). If water is obtained from private wells, water samples must be tested for their fluoride concentration.

The question of whether breast-fed infants should receive fluoride supplements is a recurring one. If the family resides in a community where the water fluoride level is less than 0.3 ppm, supplementation is indicated. A quarter-milligram of fluoride should be administered daily as recommended in Table 6.9. When the drinking water contains fluoride at a concentration of 0.3 ppm or above, the desire to afford optimal caries protection must be balanced by the concern to avoid enamel fluorosis to the developing teeth. The fluoride concentration of human breast milk is less than 0.05 ppm. This concentration does not increase significantly even if the water that the mother is drinking is optimally fluoridated. Thus, infants who are solely breast-fed do not ingest therapeutic levels of fluoride, and some authorities recommend that breast-fed infants in fluoridated communities be placed on fluoride supplements during the period of breast-feeding. However, variations in feeding regimens occur, and few infants receive all of their nutrition solely through breast-feeding. Tap water may be used to prepare juices or soft foods or may be given alone. Since feeding can not be controlled by the practitioner, nor can the practitioner guarantee that the parent will stop the fluoride supplements when breast-feeding is discontinued, it is best that fluoride supplements not be prescribed.

Because children ingest fluoride from sources other than the drinking water or dietary supplements, concern has been expressed that the combination of fluoride ingested from these controlled sources and from sources such as food, beverages, or dentifrices could cause fluorosis in susceptible-aged children (usually considered to be children under six years old).

In the late 1970s, several investigators showed that commercial milk-based formulas (whether prepared, concentrates, or powders) and commercial baby foods processed in localities served by fluoridated water could contain relatively high levels of fluoride (76-78). In addition, the reconstitution of powdered milk or milk concentrates with fluoridated water at home was found to further increase the level of fluoride being consumed by the infant (76).

As a result of these findings, food processors in the United States voluntarily limited the amount of fluoride in baby food preparations. In 1980, Ophaug and co-workers estimated the fluoride intake of two-year-olds in four dietary regions of the United States (79). Considering dietary sources of fluoride that included food, water, beverages and supplements, they calculated a daily fluoride intake of 0.045 to 0.064 mg/kg body weight for two-year-olds. These values fall within the range of 0.05 to 0.07 mg/kg which is generally considered to be the optimum range by other researchers (41,80). In addition, they found that the current daily fluoride intake from foods, exclusive of drinking water and beverages, was within the range calculated by McClure in 1943 (81). Ophaug and co-workers concluded that, "the fluoride intake

TABLE 6.9

DAILY DOSAGE OF FLUORIDE SUPPLEMENTS (mg F/DAY) ACCORDING TO AGE AND FLUORIDE CONTENT OF WATER SUPPLY

Water Fluoride Concentration (ppm)	Age		
	Birth to 24 Months	25 to 36 Months	37 Months to 13 Years
less than 0.3	0.25	0.50	1.0
0.3 to 0.7	0.0	0.25	0.5
greater than 0.7	0.0	0.0	0.0

Note: A 2.2 mg NaF tablet provides 1 mg F

from food for a two-year-old child has not significantly changed over the past 30 years."

School- and Home-Based Fluoride Supplement Programs

School-based programs have the advantage of being conducted under relatively regimented supervised conditions. Thus, it is usually assured that the participating children are regularly receiving their supplements. However, to be successful, school-based fluoride tablet programs must secure the cooperation of school administrators, teachers and parents, and must continue to sustain enthusiasm from the teachers, other school staff and participating children. Unfortunately, interest wanes with time. By the end of a six-year school-based fluoride tablet program conducted in Portsmouth, England, Allmark and co-workers reported that more than half of the participating children had left the program either because they moved out of the school district or because they lost interest (56). Another disadvantage of school-based programs is that children enter the program at age five or six, when the benefits are expected to be less than if they started earlier. In the United States, fluoride tablet programs are often implemented at the preschool level in Head Start centers, when the children are three and four years old.

Home-based programs have the advantages of being able to start the children while they are still infants and to provide the supplement every day of the year. However, both the parental initiative to start the program and the motivation needed to continue until the children reach the teenage years are uncommon. In a home-based program in Australia, only 12 per cent of 26 800 eligible children were involved (82). Similarly, in some communities in British Columbia where fluoride tablets were supplied at cost, only about 8 per cent of eligible children, 14 years or younger, participated, and, after two-and-a-half years, up to 50 per cent had dropped out (83).

6.4 PROFESSIONALLY (OPERATOR) APPLIED TOPICAL FLUORIDES

Topical application of fluoride by a dental professional is an established caries-preventive procedure. Because of the array of compounds, vehicles and methods of application, the selection of the most appropriate treatment for a particular patient can be confusing. The choice should be based primarily upon knowledge of the effectiveness of the method under the conditions of its intended use.

Fluoride Compounds

The three most commonly used fluoride compounds are neutral sodium fluoride (NaF), acidulated phosphate fluoride (APF) and stannous fluoride (SnF_2).

Neutral sodium fluoride solutions

A number of clinical studies have been performed using topically applied NaF. A representative list of these studies, involving the permanent teeth of children residing in fluoride-deficient communities, is presented in Table 6.10 (84-94). While a wide range of caries reductions has been reported, Mellberg and Ripa reviewed nineteen studies of professionally applied NaF solutions and found an average caries reduction of 29 per cent (95).

Stannous fluoride solutions

SnF_2 has been used in concentrations of 8 per cent (19360 ppm F) and 10 per cent (24200 ppm F). The eight per cent solution has been recommended for children and is the one most often used. Table 6.11 presents the results of clinical studies using eight per cent SnF_2 (86,87,90,91,94, 96-101). The studies are arranged according to whether the treatments were performed once or twice a year and only studies of two years or longer are listed. The effect of the more frequent treatment regimen is evident. Mellberg and Ripa calculated a caries reduction resulting from SnF_2 treatments of 32 per cent by averaging the results in 16 studies of one to three years' duration (95).

Acidulated phospate fluoride solutions

Table 6.12 lists the results of clinical trials in which APF solutions were applied to the permanent teeth of children residing in fluoride-deficient communities (90-92, 100, 102-109). The studies are arranged according to the number of treatments per year. As with SnF_2, the caries inhibition associated with APF is higher when the applications were made twice rather than once a year. Horowitz and Doyle (104) specifically compared the caries inhibition from annual and biannual topical applications of an APF solution. After three years, the DMFS inhibition was 30 per cent for a single application per year, and 43 per cent for two applications per year. Although a wide range of results is listed in Table 6.12, by averaging the findings of 16 clinical trials from one to four years' duration in which APF products were used, Mellberg and Ripa obtained a reduction of 28 per cent (95). This was similar to the average caries reductions of 29 and 32 per cent they observed in clinical studies of NaF and SnF_2. They, therefore, concluded that there was no difference in the clinical effectiveness of the three compounds.

Fluoride Vehicles

Traditionally, professional topical fluoride treatment has involved two steps, an initial prophylaxis followed by the application of an aqueous fluoride solution. The clinical studies listed in Tables 6.10, 6.11 and 6.12 all used aqueous solutions of the fluoride agents and they provide strong evidence that fluoride in an aqueous vehicle is an effective means of limiting dental caries. However, application of aqueous fluorides using the two-step prophylaxis/topical application method is time-consuming and costly relative to the conferred benefits. For this reason, other vehicles for topical fluoride were sought.

Professional topical fluoride agents have been formulated into gels, prophylaxis pastes and varnishes. Because the vehicle in which the fluoride is incorporated may influence its anticariogenic properties, it is important that the clinical studies with fluoride in these alternative modes be reviewed.

Fluoride prophylaxis pastes

Table 6.13 lists studies of two years' duration in which, unless otherwise indicated, the fluoride-containing prophylaxis paste was the only fluoride treatment given (92,96, 110-117). Most of the pastes tested in these studies are unavailable to dentists. There have been very few clinical studies of marketed pastes. Of the studies listed in Table 6.13 which have involved the evaluation of marketed products, the results

TABLE 6.10
CARIES-PREVENTIVE EFFECTS OF PROFESSIONALLY APPLIED NEUTRAL 2% SODIUM FLUORIDE SOLUTIONS ON THE PERMANENT TEETH OF CHILDREN RESIDING IN FLUORIDE-DEFICIENT COMMUNITIES

Study	Initial Age of Subjects (Yrs)	Study Duration (Yrs)	Number of Applications Per Year	Per cent Reduction DMFT	Per cent Reduction DMFS
Mercer & Muhler(87) (1972)	6-15	2	1	28	19
Averill et al.(85) (1967)	7-11	2	2	16	11
Torell & Ericson(86) (1965)	10	2	2		20
Howell et al.(88) (1955)	8-15	2	4[a]	24	36
Cohen & Schiffrin(89) (1953)	6-16	2	4		43
Iizuka et al.(90) (1972)	6-11	2	4	36	45
Cons et al.(91) (1970)	6-11	3	4[a]	17	11
Szwejda(92) (1971)	6-10	3[b] 3[b]	4[a] 4[a]	17 38	19 41
Bergman(93) (1953)	11-12	3	4		43
Knutson & Armstrong(84) (1946)	7-15	3	4	31	
Harris(94) (1959)	6-11	5	4	33	

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a. only treated during the first study year
b. two different application techniques employed

TABLE 6.11

CARIES PREVENTIVE EFFECTS OF PROFESSIONALLY APPLIED 8% STANNOUS FLUORIDE SOLUTIONS ON THE PERMANENT TEETH OF CHILDREN RESIDING IN FLUORIDEDEFICIENT COMMUNITIES

Study	Initial Age of Subjects (Yrs)	Study Duration (Yrs)	Number of Applications Per Year	Per cent Reduction	
				DMFT	DMFS
Horowitz & Lucye(96) (1972)	8-11	2	1	+3	+8
Torell & Ericsson(86) (1965)	10	2	1		4
Cons et al.(91) (1970)	6-11	3	1	8	8
Iizuka et al.(90) (1972)	6-11	2	1	13	23
Peterson & Williamson(97) (1962)	9-13	2	1	26	24
Gordon et al.(98) (1959)	12-13	2	1	38	38
Mercer & Muhler(87) (1972)	6-15	2	1	55	57
Grissom et al.(99) (1964)	6-11	2	2		16
Harris(94) (1959)	7-12	3	2	23	
Cartwright et al .(100) (1968)	6-14	2	2	37	
Mercer & Muhler(101) (1964)	5-15	2	2	44(68)	47(69)[a]

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a. two independent examiners

TABLE 6.12
CARIES-PREVENTIVE EFFECTS OF PROFESSIONALLY APPLIED 1.2% ACIDULATED PHOSPHATE FLUORIDE SOLUTIONS ON THE PERMANENT TEETH OF CHILDREN RESIDING IN FLUORIDE-DEFICIENT COMMUNITIES

Study	Initial Age of Subjects (Yrs)	Study Duration (Yrs)	Number of Applications Per Year	Percent Reduction DMFT	Percent Reduction DMFS
Cons et al.(91) (1970)	6-11	3	1	16	+ 1
Ingraham & William(103) (1970)	6-10	2	1	18	11
Szejda(92) (1972)	6-10	3	1	15	20
Horowitz & Doyle(104) (1971)	10-12	3	1	27	30
Iizuka et al.(90) (1972)	6-11	2	1	44	44
Wellock et al.(102) (1965)	8-12	2	1	44	52
Wellock & Brudevold(105) (1963)	8-22	2	1	67	70
Zahran(106) (1976)	7-9	4	2	2	5
Downer et al.(107) (1971)	14-15	3	2[a]	34	31
Horowitz & Doyle(104) (1971)	10-12	3	2	40	43
Cartwright et al.(100) (1968)	6-9	2	2	49	
Cobb et al.(108) (1980)	11-14	2	2	35	
Vrbic & Kosmelj (109) (1978)	10-12	3 3	1[b] 2[b]	16 29	23 31

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a. includes a prophylaxis with an APF paste and daily supervised brushing with a sodium monofluorophosphate dentifrice

b. 4% NaF in 0.1 M H_3PO_4

have been very poor (115-117). On the basis of these findings, fluoride-containing prophylaxis pastes cannot be considered cariostatic and cannot be used as a substitute for professional topical fluoride treatments.

Fluoride-containing prophylaxis pastes have also been recommended to be used prior to a professional topical fluoride application. It was felt that the application of fluoride in the preliminary cleaning step could provide an additive cariostatic benefit to the procedure over the fluoride-free paste.

There have been eight clinical studies in which a fluoride-containing prophylaxis paste has been used for preparatory tooth cleaning when a topical fluoride solution was professionally administered (96,107, 110-112, 118-121). Table 6.14 lists the results of those studies which were conducted for two years or longer (96,107, 110-112, 117,121). Unfortunately, because of the design of the studies, most cannot answer the question of whether a fluoride-containing prophylaxis paste used in conjunction with an aqueous topical fluoride application could provide greater caries protection than a professional application of topical fluoride preceded by a fluoride-free paste. Of the two studies designed to answer this question, neither found the combination of a fluoride-containing paste and a topical fluoride application to be superior to a topical fluoride treatment that was preceded by a prophylaxis with a fluoride-free paste (96,117). In one of these studies, however, none of the treatment groups derived any benefits from the various fluoride treatments (96).

The conclusion that there is a lack of a cariostatic effect from fluoride-containing prophylaxis pastes, when used alone or preceding a topical application of a fluoride solution, is consistent with the United States Food and Drug Administration's failure to recognize any fluoride-containing prophylaxis paste as therapeutic and with the absence of these pastes on the American Dental Association's list of accepted therapeutic agents.

What is the role of fluoride-containing prophylaxis pastes in preventive dentistry? Whenever teeth are polished with a prophylaxis paste, a thin layer (approximately 5 um) is abraded, resulting in the loss of fluoride from the tooth surface (122,123). While the clinical significance of this loss has never been studied, conventional wisdom deems the loss to be undesirable. Fluoride-containing prophylaxis pastes may replace the fluoride lost during polishing (124). The presence of fluoride in these pastes, therefore, does no harm and may be beneficial.

Fluoride gels

Fluoride gels may be used with disposable trays so that the entire mouth can be treated in a single four-minute application. Biting pressure on the trays maintains the gel in contact with the teeth, leaving the operator free to treat more than a single patient at a time. Since their introduction, fluoride gels have gained wide acceptance (125,126). Gel tray treatments are tolerated by children and appear to be the commonest method by which professionals apply fluoride in the dental office (126).

Table 6.15 adapted from Brudevold and Naujoks (125), lists four clinical studies in which APF solutions and gels have been compared (91,103,104,107). Neither method gives consistently superior results. Nevertheless, gels are preferred because of the decreased treatment time and ease of application when used with trays.

Results of clinical trials testing the professional administration of APF gels are listed in Table 6.16 (91,103,104,108, 128-132). Because the APF gel tray treatment is the most frequently used method of professional topical fluoride application, more details of these studies are presented than are found in previous tables describing other topical fluoride methods. By averaging the results of the listed studies, a composite DMFS reduction of 23 per cent is obtained. This is less than the 28 per cent reduction calculated for APF solutions. It is impossible to determine whether the difference reflects a true superiority for

TABLE 6.13

CARIES-PREVENTIVE EFFECTS OF PROFESSIONALLY APPLIED FLUORIDE PROPHYLAXIS PASTES

Study	Agent & Abrasive	Initial Age of Subjects (Yrs)	Study Duration (Yrs)	Number of Applications Per Year	Per cent Reduction DMFT	Per cent Reduction DMFS
Horowitz & Lucye(96) (1966)	8.9% SnF_2, lava pumice	8-10	2	1	+7.9	+5.9
Szwejda(92) (1971)	SnF_2[b]	6-10	3 3	1 1	17 19	19 20
Peterson et al.(113) (1969)	2% KF, H_3PO_4, lava pumice	11-13	2	1	19(8)	15(12)[a,c]
Szwejda(114) (1972)	1.23% APF sodium metaphosphate	6-10	3	1	23	18[d]
Scola & Ostrom(111) (1968)	17.5% SnF_2, lava pumice	17-24	2	1	26	12
Barenie et al.(116) (1976)	1.23% APF, SiO_2	9-14	2	2	+7(+8)	+5(+8)[a]
DePaola & Mellberg(115) (1973)	1.23% APF, SiO_2	10-13	2	2	17	21
Beiswanger et al.(117) (1980)	9% SnF_2, $ZrSiO_4$	8-16	3	2	17	15[e]
Bixler & Muhler(112) (1966)	8.9% SnF_2, lava pumice	5-18	3	2	33	35
Peterson et al.(110) (1963)	17.5% SnF_2, silex	10-13	2	2	35(39)	42(34)[a]

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a. two independent examiners
b. no other information given about the composition of this paste
c. optimally fluoridated community
d. prophylaxis followed by APF rinse
e. water F fluctuated from 0.0 to 0.8 ppm

$Si0_2$ = silicon dioxide

$ZrSi0_4$ = zirconium silicate

TABLE 6.14

CARIES-PREVENTIVE EFFECTS OF COMBINATIONS OF PROFESSIONALLY APPLIED FLUORIDE PROPHYLAXIS PASTES AND TOPICAL FLUORIDE SOLUTIONS

Study	Fluoride Treatments	Initial Age of Subjects (Yrs)	Study Duration (Yrs)	Number of Applications Per Year	Per cent Reduction DMFT	Per cent Reduction DMFS
Horowitz & Lucye (96) (1966)	P	8-11	2	1	+8	+6
	T				+2	+8
	P + T				+3	1
Scola & Ostrom (111) (1968)	P	17-24	2	1	26	12
	P + T				34	27
Peterson et al. (110) (1963)	P	10-13	2	1	28	34
	P + T				29	32
	P		2	2	35	42
Downer et al. (107) (1976)	P + T + D[c]	11-12	3	2	34	31
Bixler & Muhler (112) (1966)	P	5-18	3	2	29(36)	29(38)[a]
	P + T				39(58)	40(56)
Beiswanger et al. (117) (1980)	P	8-14	3	2	17	15
	T				47	52
	P + T				45	52
Muhler et al. (121) (1967)	P + T + D	Dental Students	2.5	2	68	64[b]

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a. two independent examiners

b. optimally fluoridated community

c. Na_2PO_3F is the active ingredient in D; APF is the active ingredient in P and T; in all other studies, SnF_2 is the active ingredient in P, T, and D

P = fluoride-containing prophylaxis paste
T = professional topical fluoride application
D = fluoride-containing dentifrice

TABLE 6.15

COMPARISON OF THE CARIES-PREVENTIVE EFFECTS OF PROFESSIONALLY APPLIED APF TOPICAL SOLUTIONS AND GELS

Study	Per cent DMFS Reduction	
	Solution	Gel
Cons et al.(91) (1970)	0	18
Ingraham & Williams(103) (1970)	12	41
Szwejda(127) (1972)	23	4[a]
Horowitz & Doyle(104) (1971)	28	24

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a. optimally fluoridated community

Source: (125)

solutions since studies in which both APF vehicles were tested did not produce consistent results (see Table 6.15). Most studies of an APF gelincluded only one topical treatment a year. It may be that the lower average reduction reflects this infrequent application schedule. Of interest is the finding that in the two studies which re-examined children one and two years after discontinuing treatment, the benefits persisted (128,130).

Fluoride varnishes

Although no clear relationship has been shown between an individual's fluoride concentration in the outer enamel and caries activity (133), it is generally believed that higher concentrations are desirable (134). Increasing the duration of exposure to the topical fluoride agent can increase the enamel fluoride concentration (135-137). With conventional topical compounds, the fluoride contact is short, generally four minutes, and there is a substantial leaching of absorbed fluoride from the enamel surface during the first twenty-four hours (138,139). To prevent this immediate loss and to increase enamel fluoride uptake, fluoride has been incorporated into varnishes that adhere to the enamel for long periods and slowly release the fluoride to the teeth. The varnishes stick to the enamel for twelve hours or longer; thus, they increase the fluoride contact time without increasing chair time and, presumably, allow greater enamel fluoride uptake and permanence. The first fluoride varnish, Duraphat^R, was initially used by Heuser and Schmidt in 1968 (140). A viscous yellowish material, Duraphat^R contains 2.3 per cent fluoride (22600 ppm F) as sodium fluoride in an alcoholic solution of natural varnishes. Another commercially available product, FluorProtector^R, is a thin, clear polyurethane material containing one per cent difluorosilane, an organic fluoride with a concentration of 0.7 per cent fluoride (7000 ppm F).

TABLE 6.16

CARIES-PREVENTIVE EFFECTS OF PROFESSIONALLY APPLIED 1.2% APF GELS ON THE PERMANENT TEETH OF CHILDREN RESIDING IN FLUORIDE-DEFICIENT COMMUNITIES

Study	Initial Age of Subjects (Yrs)	Study Duration (Yrs)	Number of Applications Per Year	Per cent Reduction		Baseline DMFS		DMFS Increment		DMFS Saved Per Year
				DMFT	DMFS	Control	Treated	Control	Treated	
Horowitz & Doyle (104) (1971)	10-12	3	1	16	24	9.03	8.81	8.61	6.51	0.70
Horowitz & Kau (128) (1974)		5	a		21	9.27	9.29	13.03	10.31	0.54
Bryan & Williams (129) (1968)	8-12	1	1	45	28	8.07	7.72	3.87	2.77	1.10
Bryan & Williams (130) (1970)		2	b	45	37	8.14	8.37	7.26	4.56	1.35
Szwejda (131) (1971)	7-8	2	1	3	4	1.58	1.68	2.15	2.07	0.04
Ingraham & Williams (103) (1970)	6-10	2	1	52	41	2.55	2.32	3.13	1.84	0.65
Cons et al. (91) (1970)	6-11	4	1	25	18	2.68	3.16[c]	3.82	3.14	0.23
Mainwaring & Naylor (132) (1978)	11-15	3	2		14	7.59	8.19	8.27	7.10	0.39
Cobb et al. (108) (1980)	11-14	2	2[e]		35	6.01	5.38[d]	8.15	5.28	1.44

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a. no additional applications; examined 2 yrs. after discontinuation of treatment
b. no additional applications; examined 1 yr. after discontinuation of treatment
c. baseline DMFS for first permanent molars only
d. baseline DMFS for those starting study; for all others, baseline DMFS is for those completing study
e. trays not used; for all others, APF administered in trays

Since the first clinical report of a fluoride varnish, at least two dozen reports of clinical studies have appeared (see reviews [141-144]). With one exception (145,146), none of the clinical studies of fluoride varnishes has been conducted in North America. Because of the changing caries prevalence in different countries, it is recognized that results from one country might not be directly extrapolated to other countries where either the caries pattern or rate of attack might be different. For this reason, it is important to examine the results of the single North American study testing fluoride varnishes. This study was conducted by Clark and co-workers in Sherbrooke and Lac Megantic, two fluoride-deficient communities in Quebec (145,146), and initially involved 787 first grade children (six- to seven-year-olds) who were treated twice a year with either FluorProtector^R, Duraphat^R, or a water control.

Because of the young age of the patients, treatment effects in the permanent dentition were limited mainly to the first molars. In addition, caries of the primary molars was evaluated. As seen in Table 6.17, the difference in caries activity between the control and treatment groups was low and not statistically significant after 20 months. The results after 32 months showed higher percentage reductions, especially for primary molars treated with Duraphat^R; however, these results were presented in abstract form and the investigators did not indicate the statistical significance of the findings. Nevertheless, their clinical implications may be deduced. The children received five or six treatments during the three-year study period. With each treatment requiring 20 minutes (to do a thorough prophylaxis using a rubber cup, prophy brush, and dental floss, isolate and dry the teeth, and apply the varnish), the total professional time involved was one and two-thirds to two hours per child. The maximum protection, which occurred in the Duraphat^R treated group, was only 0.7 permanent tooth surface and 0.6 primary tooth surface. Thus, the cost in professional time and actual dollar amount may not justify the savings in carious tooth surfaces if this approach was considered for a public health program. However, it must be recognized that because of the age of the patients, 95 per cent of the permanent caries increment during this study involved the pits and fissures of first molars. By designing a study that did not include the opportunity for much smooth surface decay, the test of these products' effectiveness was very limited.

Professional Application of Topical Fluorides in Different Clinical Situations

Most clinical trials of professionally applied fluoride agents have been conducted on children in fluoride-deficient communities and have usually been limited to the permanent teeth. Other clinical situations in which knowledge of the efficacy of topical fluoride treatments is important are: 1) when used in optimally fluoridated communities; 2) when used on the primary teeth of young children; and 3) when used in adults. Clinical studies testing professionally applied fluoride treatments in these situations have been reviewed by Mellberg and Ripa (95), Ripa (147) and Swango (148).

Use of professional topical fluorides in optimally fluoridated communities

Generally, the degree of caries reduction observed in fluoride-deficient communities has not been achieved in fluoridated communities. Consequently the routine use of professional topical fluoride treatments to residents of optimally fluoridated communities, either in public health programs or programs of individual patient care, cannot be recommended. However, if individual patients exhibit relatively high caries attack rates, despite the presence of fluoride in the drinking water, they should receive professional topical fluoride treatments.

Use of professional topical fluorides on primary teeth

Results of studies testing professionally applied topical fluorides on the primary teeth of children generally have been positive; however, the caries reductions reported for primary teeth usually are not as great as those reported for permanent teeth. There have been no clinical studies in which fluoride gels have been applied professionally to the primary teeth. Results

TABLE 6.17

CARIES-PREVENTIVE EFFECTS OF THE SHERBROOKE-LAC MEGANTIC FLUORIDE VARNISH STUDY ON THE PERMANENT AND PRIMARY TEETH OF 6- AND 7-YEAR-OLD CHILDREN

Study Duration (Yrs)	Number of Applications Per Year	Treatment	Per cent Reduction (DMFS)	Baseline DMFS	DMFS Increment	DMFS Saved Per Year
Results in Permanent Teeth						
20 Months[a]	2	FP	16	0.35	1.70	0.16
		D	14	0.40	1.73	0.15
		C	--	0.35	2.02	----
32 Months[b]	2	FP	17		2.57	0.18
		D	22		2.42	0.23
		C	--		3.11	----

Results in Primary Molars

Study Duration (Yrs)	Number of Applications Per Year	Treatment	Per cent Reduction dfs	Baseline dfs	dfs Increment	dfs Saved Per Year
20 Months[a]	2	FP	10	Not Given	1.56	0.09
		D	7		1.62	0.06
		C	--		1.74	----
32 Months[b]	2	FP	10		1.89	0.06
		D	29		1.47	0.20
		C	--		2.06	----

FP = FluorProtector[R]

D = Duraphat[R]

C = Control

a. source: (145)
b. source: (146)

with the fluoride varnish, Duraphat^R, seem to be more favourable (see review by Schmidt [142]). On the other hand in a study by Grodzka and co-workers, there was no effect when Duraphat^R was applied twice a year for two years to three-year-old Polish children (149) nor were the results of Clark and co-workers that were obtained in Quebec children (see Table 6.17) very promising (145,146). Since absolute dryness is not critical when Duraphat^R is applied, better results might be expected with this vehicle than with fluoride solutions or gels when very young children, in whom the maintenance of a dry field is difficult, are being treated.

Use of professional topical fluorides for adults

There have been less than a dozen studies of professionally applied fluoride treatments in adults (see reviews 95, 147, 148). Although a review of these studies indicates that topical fluoride applications to the permanent teeth of adults can be beneficial, the fluoride agents tested and the methods employed in the reported studies are not widely used today. The agent and method most often used by today's dentists, APF gel in trays, has not been tested in adults. Furthermore, there have been no clinical studies which have evaluated the effectiveness of topical fluoride treatment in preventing root caries, nor have any studies involved subjects much older than 40 years.

Compared to children, noncarious coronal surfaces in adults are less likely to decay. Thus, the potential benefit of topical fluoride applications in adults is less than in children because of the decreased caries susceptibility of the remaining caries-free surfaces. Nevertheless, if individual adult patients present with new carious lesions of the coronal or root surfaces, they should receive professional topical fluoride treatments.

Method of Professional Topical Fluoride Application

When aqueous solutions of NaF, SnF_2 or APF are used, the solution is applied to cleaned, dried and cotton roll isolated teeth using cotton tipped applicators. In North America, however, fluoride solutions have been replaced principally by APF gels which are applied in disposable trays.

As a preliminary step when using a fluoride gel, the teeth were cleaned with a dental prophylaxis paste and unwaxed dental floss. The rationale for this step was to remove plaque and pellicle that might act as barriers to fluoride uptake by the enamel and thus reduce the clinical effectiveness of the topical fluoride treatment (139,150).

Within the past decade, in vivo (151-154) and in vitro (155-157) studies have demonstrated that fluoride uptake was not impeded by surface organic integuments (see review by Ripa [158]), and several of these reports questioned the need to continue to routinely precede a topical fluoride treatment with a prophylaxis (151-155, 159).

Three independent clinical studies were initiated to answer this question (160-163). Each study included biannual applications of APF gel administered in trays. Each included three study groups: one received a meticulous hygienist-administered prophylaxis before an APF gel tray treatment. This was the positive control. Another group brushed and flossed their own teeth under supervision before receiving the same topical fluoride treatment. The third group participated in no tooth cleaning before their topical fluoride treatment. The results of the three studies are presented in Table 6.18. There were no statistically significant differences in the DMFS increments between the three groups. Based upon these results, it is no longer recommended that a prophylaxis be routinely performed when giving a topical fluoride treatment. A professional cleaning should be considered for cosmetic reasons to remove extrinsic stains or to establish a baseline level of oral cleanliness in a patient with gingival disease. However, the prophylaxis is no longer considered a categorical prerequisite before a professional topical fluoride application.

Based upon the foregoing, the currently recommended method of performing a

TABLE 6.18

MEAN DMFS INCREMENTS OF CHILDREN RECEIVING BIANNUAL PROFESSIONALLY APPLIED APF GEL-TRAY TREATMENT WITH OR WITHOUT A PRIOR TOOTH CLEANING

Study	Ripa et al.(160)	Houpt et al.(161)	Katz et al.(162)	Ripa et al.(163)
Duration	2 yrs.	2 yrs.	2.5 yrs.	3 yrs.
prophylaxis + topical F	2.12	2.05	2.23	3.33
self-brush + topical F	1.87	2.48	2.33	3.18
topical F	2.02	2.14	2.09	3.19

professional topical fluoride treatment using a gel-tray system is:

1. Have the patient rinse with water to remove food particles.

2. Fit stock trays to the upper and lower arches. Fill each tray with no more than 2.5 ml of gel (one-half teaspoonful per tray).

3. Insert both upper and lower trays over the teeth and have the patient close on a saliva ejector placed in the floor of the mouth. Any excess gel that might ooze from the periphery of the trays should be expectorated or aspirated by the saliva ejector. Leave the trays in the mouth for four minutes.

4. Remove trays and aspirate the mouth with a high-suction aspirator. The patient should expectorate but is instructed not to rinse, eat or drink for thirty minutes.

Although there are an insufficient number of clinical studies done in which an APF gel has been professionally administered twice a year (see Table 6.16), it is generally conceded that, for best results when applying high concentrations of fluoride, two applications a year should be made.

Method when using a fluoride varnish

The manufacturer's directions for Duraphat^R state that the varnish should be applied with cotton tipped applicators to cleaned and "provisionally-dried teeth" treating either a quadrant at a time or half a mouth. The different quadrants can be treated quickly because a four-minute waiting period is not necessary. Immediately after Duraphat^R is applied to all of the teeth, the patient may close his mouth since the varnish hardens in saliva.

6.5 SELF-APPLIED TOPICAL FLUORIDES

Topical fluorides may be applied to the teeth by the patients themselves; this has the advantage of enabling many more fluoride contacts than can be accomplished by professional administration. The most common method of self-application is brushing the teeth with a fluoride-containing dentifrice. This method is discussed in Section 6.6. The three methods of self-application described in this section are:

1. Toothbrushing. Brushing is performed with a topical fluoride agent. Fluoride-containing prophylaxis pastes, topical gels and solutions have all been used with this technique.
2. Mouth Trays. Several drops of fluoride gel are placed into custom-fitted or disposable stock mouth trays. The trays are worn for several minutes, allowing the gel to contact the teeth.
3. Mouthrinsing. A measured amount of fluoride solution is rinsed and expectorated.

Although investigations of these methods have been prompted by their applicability for community-based public health programs, they can be used also by individual dental patients (164). When used regularly by conscientious patients in their own homes, these methods should provide similar benefits to those observed when they are performed under supervision.

Self-Applied Brushing Methods

There have been approximately two dozen reports in which fluoride solutions, gels or prophylaxis pastes have been applied to the teeth in programs involving frequent self-brushing (see reviews [164-167]). Because these studies failed to demonstrate a uniformity of results, no review of topical fluoride self-application methods supports brushing as a means of achieving caries inhibition. Recently, the self-applied brushing of a 0.4 per cent SnF_2 gel in individual home preventive programs has become popular. The manufacturers of these SnF_2 gels claim that they are effective caries-preventive agents and are useful in controlling gingivitis. The Council on Dental Therapeutics of the American Dental Association has accepted more than a dozen commercial 0.4 per cent SnF_2 gel products on the basis of their purported caries-inhibitory effects (168) but has emphasized that their long-term effectiveness in controlling gingivitis has not been established (169).

A 0.4 per cent SnF_2 gel contains 1000 ppm fluoride. This concentration of fluoride is the same as that used in the original Crest^R formulation. Thus, by association, the 0.4 per cent SnF_2 gels are believed to be effective caries-preventive agents. However, since the gels do not contain an abrasive, they cannot be used in place of a regular dentifrice. If a conscientious patient is already brushing one or more times a day with a fluoride-containing dentifrice, it is not known whether an additional daily brushing with another product containing the same concentration of fluoride will provide any additional benefit. Until the efficacy of these products has been tested in situations that realistically duplicate the way they are meant to be used, i.e. by individuals who are regularly using fluoride dentifrices, they cannot be unequivocally recommended for individual home-based caries preventive programs, despite their acceptance by the American Dental Association. The 0.4 per cent SnF_2 gel has been recommended for use in high-caries-risk patients, such as those with radiation xerostomia, and largely anecdotal reports indicate their usefulness in this situation (170).

Self-Applied Methods Using Fluoride Gels and Mouth Trays

There have been four reports in which fluoride gels in trays have been tested in children residing in fluoride-deficient communities (171-174) and three reports in which they have been tested in optimally fluoridated communities (175-177), plus one report in which the primary dentition was treated (178). As seen in Table 6.19, the agent usually tested was APF at a fluoride concentration of 1.23 per cent (12300 ppm) or 0.5 per cent (5000 ppm). The application frequency varied widely from once every school day for the duration of the program to five applications during five consecutive days at the start of the program. On the basis of the studies listed in the table, self-applied topical fluoride gel tray applications can be considered a proven caries-preventive method.

In the Englander and co-worker's supervised studies, application of a high-concentration fluoride gel (5000 ppm) applied frequently (three to five times a week) proved a very effective method of caries control. This same combination of a high-concentration gel, applied

TABLE 6.19

CARIES-PREVENTIVE EFFECTS OF SELF-APPLIED FLUORIDE GELS IN MOUTH TRAYS ON THE PERMANENT TEETH OF CHILDREN RESIDING IN FLUORIDE-DEFICIENT AND OPTIMALLY FLUORIDATED COMMUNITIES

Study	Treatment	Subjects' Age (Yrs)	Study Duration	Application Frequency	Per cent Reduction	
					DMFT	DMFS
Fluoride Deficient Communities						
Englander et al. (171) (1967)	APF gel (0.5% F, pH 4.5)	11-14	21 months	1x/day	75	64
	NaF gel (0.5% F, pH 7.0)	11-14	21 months	1x/day	80	67
Englander et al. (172) (1969)	APF gel (0.5% F, pH 4.5)	11-14	44 months[a]	no additional treatment	70	70
	NaF gel (0.5% F, pH 7.0)	11-14	44 months[a]	no additional treatment	69	70
Trubman & Crellin (173) (1973)	brushed with non-F prophy paste followed by APF gel (1.23% F, pH 3.0)	8.1	3 years	4x/year	23	35
	brushed with APF prophy paste followed by APF gel (1.23% F, pH 3.0)	8.1	3 years	4x/year	25	22
Shern et al. (174) (1976)	APF gel (1.23% F, pH 3.2)	6-13	2 years	1x/day for 5 days[b]		+0.5
	amine F gel (1.25% F, pH 4.5)	6-13	2 years	1x/day for 5 days[b]		32
	amine F gel (1.25% F, pH 4.5)	6-13	2 years	1x/week for 5 weeks[c]		25
Optimally Fluoridated Communities						
Englander et al. (175) (1971)	APF gel (0.5% F, pH 4.5)	11-15	27-31 months	3x/week	—	29
Mellberg et al. (176) (1978)	APF gel (1.23% F, pH 3.2)	9-12	1 year	1x/day for 5 days[b]		7
	APF gel (1.23% F, pH 3.2)	9-12	1 year	1x/day for 10 days[b]		30
	APF gel (1.23% F, pH 3.2)	9-12	1 year	1x/day for 25 days[b]		35
Heifetz et al. (177) (1979)	APF gel (1.23% F, pH 3.2) + weekly mouthrinsing with 0.2% NaF (0.09% F)	10-11	30 months	1x/day for 1 week; repeated 3x/year (15 total app/yr)		30

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a. includes 21 months of treatment and 23 months posttreatment
b. consecutive week days
c. consecutive weeks

frequently, should also provide substantial caries protection to motivated patients whose caries experience places them in a high-risk category.

There are neutral and acidulated fluoride gels available for home use that contain 5000 ppm F. These may be stocked in the dental office and dispensed to patients by the dentist. At the same time, horseshoe-shaped maxillary and mandibular polyvinyl mouthtrays must be constructed from casts of the patients' dental arches. Patients are instructed to place approximately 2.5 ml of gel (one-half teaspoonful) in each tray and to wear them for five minutes each night before bedtime. After application, the patient should rinse his mouth with water to remove any gel that may cling to the teeth and must wash, dry and store the trays.

Currently, some manufacturers of fluoride products are recommending that their 5000 ppm F gels be applied by brushing rather than with a custom tray. Toothbrushing application is more convenient than using trays. However, there have been no clinical studies in which either neutral or acidulated NaF gels, in a concentration of 5000 ppm F, have been tested in a self-applied brushing program.

Fluoride Mouthrinsing

Fluoride mouthrinsing is an established cariostatic method (see reviews 166, 179-184), and is the second most widely used public health caries-preventive method, second only to community water fluoridation. Although a variety of fluoride compounds, fluoride concentrations and treatment frequencies have been employed in clinical studies of fluoride mouthrinsing (166), two regimens in particular have proved effective in numerous clinical trials and have been employed in either individual programs of patient care or in school-based community programs. These are a 0.05 per cent NaF rinse (230 ppm F) used daily or a 0.2 per cent NaF rinse (900 ppm F) used weekly or every two weeks (185).

Despite the variety of methods and agents, studies of fluoride mouthrinsing have given consistently positive results with reductions rarely less than 25 to 30 per cent. This is true even when the rinsing was conducted in communities with optimum water fluoridation. While reports of fluoride mouthrinsing have appeared since the 1940s, most North American studies were reported since 1970, and it is these studies that are listed in Table 6.20 (54, 186-197) and Table 6.21 (198-202).

Because of their ease of implementation (203), school-based mouthrinsing programs in North America usually involve rinsing once a week with a neutral 0.2 per cent NaF solution (900 ppm). Rinsing begins in the earliest grade level possible and continues to the highest grade within the school. While the cooperation of children in the lower grades is usually excellent, both DePaola and co-workers (204) and Eckhaus and co-workers (205) have commented on the difficulty of conducting a mouthrinse program with high school (grades nine through twelve) children. Rinsing is performed under supervision and there is no need to clean the teeth before rinsing (206). The children swish 10 ml of solution in their mouth for 60 seconds and then expectorate into paper cups. Dispensing the fluoride and supervising rinsing takes approximately five minutes per classroom.

For individual home use, the 0.05 per cent NaF rinse (230 ppm F) is recommended (185). These products can be purchased in stores without prescription and several commercial products are available. The patient should rinse with 5 or 10 ml, once a day, at a time that is convenient, usually in the morning or at bedtime. Because young, preschool children might swallow rather than expectorate much of the solution (207-210), the over-the-counter rinses are not intended for children younger than six years.

6.6 FLUORIDE IN DENTIFRICES

Fluoride dentifrices are the most widely used individual method of preventing dental caries. The first formal recognition that a fluoride-containing dentifrice was safe and effective in reducing dental caries occurred in

TABLE 6.20

CARIES-PREVENTIVE EFFECTS OF FLUORIDE MOUTHRINSING ON THE PERMANENT TEETH OF CHILDREN RESIDING IN FLUORIDE-DEFICIENT COMMUNITIES: NORTH AMERICAN STUDIES

Study	F Compound	F Concentration (ppm)	Rinsing Frequency	Subjects Age (Yrs)	Study Duration	Per cent Reduction		Baseline DMFS		DMFS Increment		DMFS Saved Per Year	Final Sample Size	
						DMFT	DMFS	Control	Treated	Control	Treated		Control	Treated
Horowitz et al.(186) (1971)	NaF	900	1x/week	6	20 months	25	16	0.97	0.90	1.3	1.1	0.12	135	125
	NaF	900	1x/week	11	20 months	52	44	6.48	6.97	2.9	1.7	0.72	112	117
Heifetz et al.(187) (1973)	NaF	3000	1x/week	10-12	24 months		38	9.28	8.52	7.5	4.7	1.40	154	126
	APF	3000	1x/week	10-12	24 months		28	9.28	9.38	7.5	5.5	1.00	154	133
Gallagher et al.(188) (1974)	NaF	1800	1x/week	11-13	24 months	34	34	7.37	7.19	4.4	2.9	0.75	288	306
DePaola et al.(189) (1977)	APF	1000	1x/day	10-12	24 months		42	6.47	5.46	7.6	4.4	1.60	158	158
	NH_4F	1000	1x/day	10-12	24 months		42	6.47	6.26	7.6	4.4	1.60	158	159
Ringelberg et al.(190) (1979)	NaF	250	1x/day	11	30 months	17	23	4.30	3.90	6.5	4.8	0.68	94	179
	Amine F	250	1x/day	11	30 months	17	22	4.95	4.36	6.0	4.9	0.44	92	162
Frankl et al.(191) (1972)	APF	200^a	1x/day	14	24 months	26	22	21.6	23.7	8.7	6.8	0.95	246	253
Aasenden et al.(54) (1972)	NaF	200^a	1x/day	8-11	36 months	26	27	7.99	8.58	12.3	9.0	1.1	139	114
	APF	200^a	1x/day	8-11	36 months	32	30	7.99	7.32	12.3	8.7	1.2	139	109
Packer et al.(192)	APF	200	1x/day	8	28 months		27	6.48	6.47	2.7	1.9	0.34	97	80
	APF	1000	1x/week	8	28 months		41	6.48	6.80	2.7	1.6	0.47	97	109
Finn et al.(193) (1975)	APF	100	2x/day	8-13	26 months	16	18	6.02	5.87	6.9	5.6	0.60	161	150
	APF	200	2x/day	8-13	26 months	28	29	6.02	6.17	6.9	4.9	0.92	161	142

TABLE 6.20 (Con't)

CARIES-PREVENTIVE EFFECTS OF FLUORIDE MOUTHRINSING ON THE PERMANENT TEETH OF CHILDREN RESIDING IN FLUORIDE-DEFICIENT COMMUNITIES: NORTH AMERICAN STUDIES

Study	F Compound	F Concentration (ppm)	Rinsing Frequency	Subjects Age (Yrs)	Study Duration	Per cent Reduction		Baseline DMFS		DMFS Increment		DMFS Saved Per Year	Final Sample Size	
						DMFT	DMFS	Control	Treated	Control	Treated		Control	Treated
McConchie *et al*.(194) (1977)	SnF$_2$	100	1x/day	10	24 months	20	20	6.12	6.19	5.8	4.6	0.60	247	248
	SnF$_2$	200	1x/day	10	24 months	20	17	6.12	6.39	5.8	4.8	0.50	247	248
Heifetz *et al*.(195) (1982)	NaF	900	1x/week	10-12	36 months		38[b]	7.16	6.03	3.6	2.3	0.43	87	97
	NaF	900	1x/week	10-12	36 months		24[b]	6.12	5.93	4.4	3.4	0.33	117	102
	NaF	230	1x/day	10-12	36 months		47[b]	7.16	6.82	3.6	1.9	0.56	87	88
	NaF	230	1x/day	10-12	36 months		34[b]	6.12	5.44	4.4	2.9	0.50	117	107
Ringelberg *et al*.(196) (1982)	NaF	230	1x/day	12.5	18 months		28	4.93	4.71	3.34	2.40	0.56	249	235
	NaF	900	1x/day	12.5	18 months		23	4.93	5.17	3.34	2.58	0.46	249	257
	NaF	230	1x/week	12.5	18 months		17	4.93	4.75	3.34	2.79	0.33	249	244
	NaF	900	1x/week	12.5	18 months		20	4.93	4.11	3.34	2.66	0.41	249	253
DePaola *et al*.(197) (1980)	NaF	230	1x/day	12-13	24 months		22	?	?	9.11	7.14	0.99	142	129

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a. rinse and swallowed
b. results of 2 examiners each examining different children

TABLE 6.21

CARIES-PREVENTIVE EFFECTS OF FLUORIDE MOUTHRINSING ON THE PERMANENT TEETH OF CHILDREN RESIDING IN OPTIMALLY FLUORIDATED COMMUNITIES: NORTH AMERICAN STUDIES

Study	F Compound	F Concentration (ppm)	Rinsing Frequency	Subjects Age (Yrs)	Study Duration	Per cent Reduction		Baseline DMFS		DMFS Increment		DMFS Saved Per Year	Final Sample Size	
						DMFT	DMFS	Control	Treated	Control	Treated		Control	Treated
Laswell et al.(198) (1975)	APF	200	1x/day	8-9	28 months		23	3.20	2.57	1.6	1.3	0.13	117	106
	APF	1000	1x/week	8-9	28 months		46	3.20	3.25	1.6	0.9	0.30	117	120
Radike et al.(199) (1973)	SnF_2	250	1x/day	8-13	20 months	28[a]	33[a]	4.80	4.90	3.02	2.02	0.6	378	348
						(31)[a]	(43)[a]	(5.20)	(5.28)	(2.82)	(1.60)	0.8		
Driscoll et al.(199) (1973)	NaF	900	1x/week	12-13	30 months		22[b]	4.16	4.69	2.6	2.0	0.26	77	81
	NaF	900	1x/week	12-13	30 months		35[b]	5.74	4.83	1.9	0.9	0.39	74	84
	NaF	225	1x/day	12-13	30 months		28[b]	4.16	3.96	2.6	1.9	0.27	77	102
	NaF	225	1x/day	12-13	30 months		50[b]	5.74	5.25	1.9	1.0	0.36	74	106
Kawall et al.(200) (1981)	NaF	900	1x/week	9-10	24 months		35	4.59	4.18	1.33	0.87	0.23	270	219
Bell et al.(202) (1984)	NaF	900	1x/week	Grades 1 & 2	Approx. 42 months		16[c]	?	?	2.59	2.18	0.10	146	132
							0[c]	?	?	1.34	1.56	0.00	168	145
							7[c]	?	?	2.72	2.52	0.05	110	132
							0[c]	?	?	2.12	2.34	0.00	149	236

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a. results of 2 examiners each examining same children
b. results of 2 examiners each examining different children
c. 4 different communities

1960 (211). Since that time, other dentifrices containing fluoride have also been recognized for their anticaries properties. Both the dental profession and the public are aware of the therapeutic value of fluoride dentifrices and sales of these products constitute 80-90 per cent of the total dentifrice market. Undoubtedly, the widespread use of fluoride dentifrices has contributed to the caries decline that has been reported in many countries (212).

The two most common sources of fluoride used in currently marketed dentifrices are sodium fluoride (NaF) and sodium monofluorophosphate (Na_2PO_3F).

There have been approximately 150 published clinical studies of fluoride dentifrices. Three excellent reviews of dentifrice studies have appeared recently (213-215). Mellberg and Ripa grouped the results of clinical trials of sodium fluoride, stannous fluoride, and sodium monofluorophosphate according to their reported caries inhibition (213). As seen in Figure 6.3, the most frequently observed caries inhibition from the use of these dentifrices is 21 to 30 per cent.

The question of which dentifrice provides the best protection against dental caries is a pertinent one for both dentists and the public. Based upon his review of the literature, Stookey concluded that a NaF-containing dentifrice was superior to other currently marketed dentifrices (215). However, DePaola felt that evidence of superiority of one commercial paste over another was inconclusive (214). Clinical studies are designed to test a dentifrice in a program that lasts for two or three years and involves a narrow age range. In actuality, fluoride dentifrices are meant to be used for a lifetime. Under those conditions, it is highly likely that all currently marketed and accepted fluoride dentifrices will perform similarly. Dentists should recommend that their patients use a fluoride dentifrice which has been accepted by the Canadian or American Dental Association. The use of fluoride dentifrices continuously over the lifetime of the individual should result in the maximum protection to the dentition possible with this method.

6.7 FLUORIDE-CONTAINING DENTAL CEMENTS

Different fluoride compounds have been added to zinc phosphate cements (216,217), silicophosphate cements (218), and polycarboxylate cements (219,220). The fluorosilica glass in the powder of glass ionomer cements is similar to that of silicate cements and special attention has focused on this material (221,222). A one-year in vitro study reported that glass ionomer restorative materials and cements release fluoride in amounts similar to that released by silicate cement, and the investigators concluded that the glass ionomers should have the same long-term anticariogenic properties as the silicates (221). It must be remembered, however, that studies of fluoride availability are preliminary to, and not substitutes for, clinical caries trials. To date, no controlled long-term clinical trials have been conducted with any of the fluoride-containing cements. Nevertheless, since dental cements and luting agents are routinely used in clinical dentistry, it is prudent to select a product with available fluoride.

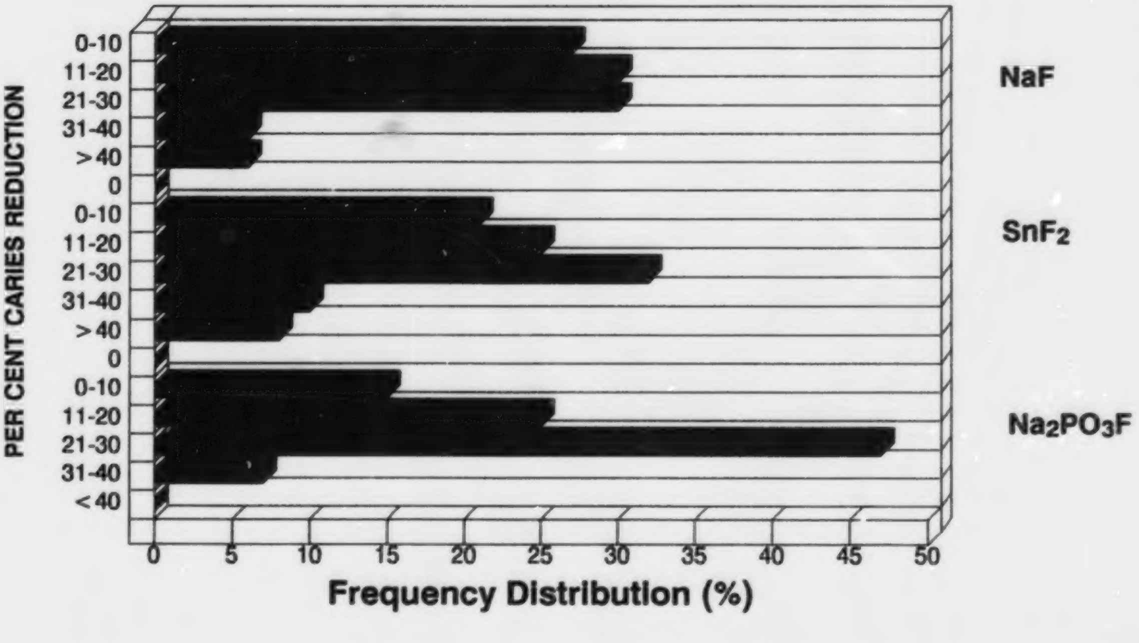
6.8 NEW FLUORIDE METHOD

The most innovative fluoride method currently under study is an intraoral controlled-release fluoride delivery system (223-227). The objective of this method is to provide fluoride at a constant dose for several months after intraoral insertion of the device. A small copolymer capsule consisting of a central core sandwiched between a copolymer membrane is attached to the buccal surface of a molar tooth. Fluoride, which is contained in the central core, diffuses through the outer membrane into the oral cavity. The release of fluoride is controlled by the rate of diffusion. Because diffusion is constant, this method avoids the peaks and valleys in fluoride concentration that occur in the blood and saliva when fluoride is administered in conventional drops or tablets.

Because fluoride from an intraoral controlled-release device first enters the saliva before being swallowed, a topical as well as systemic

Figure 6.3

CARIES-PREVENTIVE EFFECTS OF FLUORIDE DENTIFRICES GROUPED ACCORDING TO THE PER CENT (DMFS) REDUCTION ACHIEVED



Source: (213)

NaF - Sodium Fluoride
SnF_2 - Stannous Fluoride
Na_2PO_3F - Sodium Monofluorophosphate

effect can be anticipated. This method, therefore, can provide a constant level of fluoride to both unerupted and erupted teeth. The method has potential for children and adults, and its usefulness in the prevention of root caries also must be explored. The next steps in the evolution of this new procedure are the development of a reliable method of attachment to the teeth and randomized clinical caries trials in humans.

6.9 SAFETY OF THERAPEUTIC FLUORIDES

Therapeutic amounts of fluoride used in recommended techniques are safe and effective. However, as with any other therapy, fluoride in inappropriately high amounts or in untested techniques poses potential hazards. These are dental fluorosis from the chronic ingestion of overly high levels of fluoride during the period of tooth formation and systemic effects associated with an acute fluoride overdose.

Community Water Fluoridation

Fluoridation of the water supply does produce fluorosis in some individuals. However, there are different degrees of fluorosis and at optimal water fluoride levels (0.7 to 1.2 ppm F), the cosmetic appearance of the teeth of most affected individuals is not considered to be esthetically detracting.

While no other problem has been associated with the long-term consumption of optimally fluoridated water, a recent incident in Annapolis, Maryland stresses the importance of carefully monitoring fluoride levels in water fluoridation programs (228). Fluoride was accidentally added to the water supply at a level of 30 ppm for several days. A resident being treated by kidney dialysis, using tap water instead of deionized water, expired and seven other dialysis patients became ill. These individuals were medically compromised and were not consuming water in the usual sense. No documented untoward effects were reported in the general population from this temporary consumption of high levels of fluoride.

Fluoride Supplements

Acute toxicity from fluoride supplements can occur if a large amount of fluoride is deliberately or accidentally consumed. Heifetz and Horowitz state that five to 10 grams of sodium fluoride (approximately 2.3 to 4.5 grams of fluoride) taken at one time is a Certainly Lethal Dose (CLD) for a 70 kg (150 lb) adult who does not receive treatment. These values are equivalent to 32 to 64 mg of F per kg of body weight (1). A fourth of the CLD for fluoride can be ingested without producing symptoms of serious or acute toxicity. Therefore, 8-16 mg F/kg is considered a Safely Tolerated Dose (STD). For a two-year-old child weighing 10 kg (22 lbs), the CLD is 320 mg F and the STD is 80 mg F.

To prevent accidental poisoning at any age, the American Dental Association recommends that no more than 264 mg of NaF (120 mg F) be dispensed at any one time. This applies not only to fluoride supplements but to other fluoride preparations meant for home use, such as fluoride mouthrinse. Acceptance of proven therapeutic agents is denied by the A.D.A if the product which is destined for home use exceeds the maximum 264 mg NaF guideline.

If it is suspected that a toxic amount of fluoride has been consumed, the most practical immediate first aid measure is to induce vomiting using an emetic such as syrup of ipecac or by digitally or mechanically stimulating the back of the throat (1,44). Next, soluble calcium in any form (such as limewater, $Ca(OH)_2$) should be administered to bind the fluoride in the gastro-intestinal tract. In the home, liquid or gel antacids containing aluminum or magnesium hydroxide, or copious amounts of milk, should be swallowed. The affected individual should be taken to a hospital for proper emergency treatment. Speed is important when managing a case of toxic fluoride overdosage. Usually death will occur within two to four hours after ingestion of a lethal amount of fluoride. However, death can occur in a matter of minutes. Survival for 24 hours indicates a favourable outcome.

Professionally (Operator) applied Topical Fluorides

Oral retention of from one to 35 mg of fluoride has been reported from professional topical applications of gels in children and adults (229-236) and from fluoride varnish application (237,238). Depending upon the method, as much as 75 per cent of the amount applied to the teeth can be swallowed (232).

Prudent therapy dictates that ingestion of topical fluorides be minimized. Precautions that can be taken include: 1) seating the patient in an upright position; 2 limiting the total amount of fluoride placed in the trays to 5 ml (equivalent to one teaspoonful) or less; 3) using trays with absorptive liners (233,235,239); 4) suctioning during and after treatment (240); and 5) instructing the patient to expectorate after the trays are removed (233,235).

Fluoride Mouthrinses

Young children may retain some solution (30-40 per cent [210]) when they rinse (207-210). For this reason, over-the-counter rinses bear the cautionary label that they are intended for use by individuals six years or older, and neither these nor higher concentration prescriptive rinses are recommended for use in preschool programs. For kindergarten children in school-based mouthrinsing programs, the volume of solution with which the children rinse should be reduced from 10 to 5 ml.

Fluoride Dentifrices

Retention of some of the dentifrice (25-33 per cent [208]) after brushing is not uncommon in young children (208, 241-245). Since all of the fluoride ingested may be absorbed (246), concern has been expressed that habitual swallowing of dentifrice by preschool children with developing permanent teeth could contribute to enamel fluorosis. Parents should take precautions to prevent very young children from inadvertently swallowing large amounts of fluoride dentifrice. This includes: 1) the parent placing only a "pea-size" amount of dentifrice on the bristles of the toothbrush; 2) having the children rinse thoroughly after brushing; and 3) supervising brushing to ensure that the dentifrice-saliva mixture is expectorated, not swallowed.

6.10 FLUORIDE RECOMMENDATIONS

1. Community water fluoridation, the most effective and efficient caries preventive measure currently available, should continue to form the basis of dental public health policy in Canada.

2. Where community water fluoridation is not available or can not be implemented, public health officials should consider one of the following school-based methods:

   a) school water fluoridation in which an individual school's water system is fluoridated at 4.5 times the optimal concentration;

   b) a daily fluoride tablet program using one 2.2 mg NaF tablet (1.0 mg F);

   c) a weekly fluoride mouthrinsing program using 0.2 per cent NaF solution (900 ppm F; 0.09 per cent F).

3. Where community water fluoridation is not available, dentists and physicians should prescribe dietary fluoride supplements for children. Fluoride supplementation should begin between birth and two weeks of age and should continue to be prescribed until approximately 12-13 years of age when all permanent teeth, exclusive of third molars, have erupted.

4. Prenatal fluoride supplements are not recommended.

5. Professionally (operator) applied topical fluoride treatments should be performed routinely on children who reside in fluoride-deficient communities and who do not participate in a school-based fluoride program. For children residing in fluoridated communities and for adults, the

decision to use operator-applied topical fluorides should be governed by the caries risk of the individual. The following procedures are recommended:

a) operator-applied topical fluoride treatments should be given twice a year;

b) while NaF, SnF_2, and APF are equally effective, APF (12300 ppm F; 1.2 per cent F) is preferred by most dentists;

c) APF gels are recommended over solutions because they are easier and less time-consuming to use. A total of 5 ml or less of gel should be placed in upper and lower trays which are simultaneously inserted in the mouth for four minutes;

d) it is no longer necessary to routinely perform a prophylaxis before giving a topical fluoride treatment.

6. Fluoride varnishes for professional topical fluoride treatments are promising. However, they have been insufficiently tested in North American populations.

7. Fluoride prophylaxis pastes should not be used as the sole agent when giving a professional topical fluoride treatment nor in self-applied fluoride programs. Prophylaxis pastes containing fluoride should be used whenever a cleaning is performed since they will replenish the fluoride in the surface enamel that is abraded away during polishing.

8. Dentists should recommend self-applied topical methods for home use for individual patients, in fluoride-deficient or optimally fluoridated communities, when indicated by their caries activity:

a) daily fluoride mouthrinsing is the most convenient self-application method (0.05 per cent NaF or 0.044 per cent APF rinses);

b) patients with significantly-above-average caries susceptibility should use a self-applied 1.1 per cent NaF or APF gel (5000 ppm; 0.5 per cent F) administered daily in custom-fitted polyvinyl trays or, if trays are unavailable, brushed on the teeth;

c) use of self-applied 0.4 per cent SnF_2 gel (1000 ppm; 0.1 per cent F) cannot be recommended at this time since there is no evidence that the gel, when used in conjunction with a fluoride dentifrice, provides an additional caries benefit.

9. A fluoride dentifrice accepted by the Canadian Dental Association or American Dental Association as being effective in caries prevention should be recommended to patients for daily use.

10. Fluoride-containing cements and luting agents may be used for their ability to transfer fluoride ions to adjacent enamel or dentin.

11. Systemic and topical fluorides must be used safely to avoid enamel fluorosis from chronic overdosage in children of susceptible ages and to avoid acute toxicity.

12. Individuals may receive a combination of fluoride therapies, depending upon their age and their level of caries risk. General guidelines to the multiple use of fluoride therapy are:

a) systemic fluoride therapy in the form of water fluoridation or dietary fluoride supplements should be available during the period of permanent tooth development and eruption;

b) fluoride dentifrices should be used routinely throughout life;

c) topical fluoride applications either professionally applied, self-applied, or both, should be administered based upon the caries risk of the individual.

6.11 SUGGESTED AREAS OF FLUORIDE RESEARCH

Systemic Methods

1. What is the effectiveness of prenatal fluoride supplements? (Note: Clinical studies can be designed ethically only to compare pre- and post-natal fluoride supplements versus post-natal supplements alone.)

2. What is the effectiveness of the intraoral controlled-release fluoride delivery system?
   a) effectiveness in children on primary and permanent teeth;

   b) effectiveness in adults on coronal and root caries.

What are the relative benefits of systemic and topical fluoride contact with this method?

3. What is the degree and prevalence of enamel fluorosis in children residing in:

   a) fluoridated communities?

   b) fluoride-deficient communities?

To what can the fluorosis be attributed?

Topical Methods

1. What is the effectiveness of professionally (operator) applied fluoride varnishes in North American populations?

   a) effectiveness on primary teeth;

   b) effectiveness on permanent teeth;

   c) effectiveness in fluoridated communities.

2. Is either a professional prophylaxis or a self-cleaning by tooth-brushing necessary before giving a fluoride varnish treatment?

3. What is the relative effectiveness of professionally applied fluoride varnish treatments?

   a) compared to professionally applied APF gel tray treatments;

   b) compared to self-applied fluoride methods such as weekly rinsing with 0.2 per cent NaF solution.

4. What is the effectiveness of topical fluoride methods on coronal and root caries in adults?

5. Is there an advantage to the use of acidulated fluoride products over neutral NaF products in professional or self-applied topical fluoride treatments?

6. What is the effectiveness of daily brushing with a 0.4 per cent SnF_2 gel (1000 ppm; 0.1 per cent F) in children or adults who are already using a fluoride dentifrice?

7. What is the effectiveness of daily brushing with a 1.1 per cent NaF or APF gel (5000 ppm; 0.5 per cent F) in children or adults who are already using a fluoride dentifrice?

8. Is the use of a 0.4 per cent SnF_2 gel effective against gingivitis?

9. Compared to conventional dentifrices containing a single fluoride ingredient at a concentration of 1000 ppm, what is the relative effectiveness of unconventional dentifrice systems:

   a) low potency dentifrices ($<$1000 ppm F);

   b) high potency dentifrices ($>$1000 ppm F);

   c) mixed fluoride systems, e.g. NaF and Na_2PO_3F.

10. Do alginates, which have a high fluoride concentration, have a role in caries prevention?

11. What is the most cost-effective delivery system for single and combined fluoride methods:

    a) for individual patients in home programs of caries prevention;

    b) for office programs of professional application;

    c) for school-based or community programs?

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CHAPTER 7

CHAPTER 7

DENTAL HEALTH EDUCATION

D. Locker

7.1 INTRODUCTION

Dental caries and periodontal disease, among the most widespread of human disorders, are plaque-related diseases (1). One method of helping to prevent both is the removal of plaque from the teeth and gingival margins (2). The effectiveness of optimal oral hygiene in the control of gingivitis and periodontal disease has been documented in a number of studies (3-5), and while the role of oral hygiene in controlling caries is less clear cut, a number of reports have indicated that plaque reduction can be effective in reducing the disease in both children and adults (6-10). Consequently, dental health education and the promotion of good oral hygiene practices have become an important component of the strategy to prevent dental disease.

Health education can be defined as "any combination of learning opportunities designed to facilitate voluntary adaptations of behaviour which are conductive to health" (11). Accordingly, it involves the transmission of knowledge, changes in individual behaviour and the maintenance or improvement of oral health status. The issue is not confined to dentistry, and self-responsibility for health has become a consistent theme in discussions of health and health care (12).

Despite its apparent logic and intuitive appeal, health education in general, and dental health education in particular, have been somewhat controversial and subject to vigorous debate. As a result, three perspectives on health education have emerged, each with its own view of who should be educated to do what. The "traditional" perspective is aimed at changing the knowledge and attitudinal base of individuals or groups with a view to promoting health-related behaviours. Programs using this perspective are commonly applied in schools, institutions or in dental practice. Those who advocate a "community" perspective argue that this traditional model has largely been ineffective in changing behaviour, at least in the long-term, and would rather see efforts directed at community decision makers, and not the public at large, in order to promote the implementation of water fluoridation and/or school-based fluoride programs (13,14). Those who adhere to the "political" perspective also advocate action to change the environment rather than human behaviour. However, this is to be achieved through increasing the public's knowledge of health issues and teaching people how to organize politically to challenge health damaging conditions in the community and workplace (15). This latter position more closely approximates a definition of health promotion (11). At this point it is appropriate to clarify the difference between health education and health promotion. Health promotion is a more global concept and involves "any combination of health education and related organizational, economic and environmental supports for behaviour conducive to health" (16). As such, health promotion encompasses health education, health legislation, social marketing, communication via the mass media and community organization. In combination, they seek not only to prevent illness but to promote wellness and enhance the quality of life (17). Health education is part of this process but constitutes one component of a broader approach to health.

A comprehensive review of the theory and practice of dental health education is beyond the scope of this chapter. Accordingly, attention will be confined to what has been referred to as the traditional perspective and dental health education efforts directed at individuals or groups in schools and dental practices. Nevertheless, the task remains formidable, largely because the literature is enormous, complex and inconsistent. A wide variety of approaches has been used in the effort to change oral health behaviours, involving the manipulation of many different types of social and psychological variables. The measures used to evaluate the effectiveness of educational interventions have also been many and varied, including knowledge, practical skills, attitudes, beliefs, behaviours, plaque levels, caries increments and gingival and periodontal health. To organize this body of work, major themes in the literature will be identified and studies having a bearing on different approaches reviewed.

7.2 APPROACHES TO DENTAL HEALTH EDUCATION

Approaches to dental health education can be broadly classified as individualistic, micro-social and macro-social (16). The individualistic approach focuses on psychological factors such as knowledge, attitudes, beliefs and emotions and the way these may be subject to behaviour modification techniques.

TABLE 7.1

SUMMARY OF APPROACHES TO DENTAL HEALTH EDUCATION

	Approach	Focus	Strategy
1.	Individualistic	Behaviour modification through changes in knowledge, attitude or belief.	i. Information Provision of information Skill development Repetitive learning
			ii. Behavioural Positive reinforcement Material rewards
			iii. Cognitive Health beliefs Fear arousal Self-efficacy
2.	Microsocial	Effect on behaviour of interaction with individuals or small groups.	Peer group influences Dental provider-patient communication Counselling in dental practice
3.	Macrosocial	Impact on behaviour of broad economic, political and socio-cultural variables.	

Micro-social approaches stress the effects on behaviour of interaction between individuals and within small groups, including the patient-practitioner relationship, while macro-social approaches emphasize socio-cultural factors, the media and the broad economic and political structures which influence health and health-related behaviours (18). These approaches and associated interventions are summarized in Table 7.1. Since it is not possible to provide a comprehensive review of the literature covering these diverse views, this chapter will largely be devoted to individualistic and microsocial factors and their implications for the practice of dentistry.

The Individualistic Approach

The individualistic approach has provided the foundation for dental health education programs offered in schools or other institutions and can readily be applied to clinical dental practice. These programs, which have been extensively tested in research using experimental designs, vary according to whether their underlying strategy has involved the manipulation of informational, behavioural or cognitive factors.

Information strategies in dental health education see the provision of information as the central, if not the only, task involved in initiating and maintaining favourable oral health behaviours. A number of reviews of the literature on school-based programs have indicated that this has been their primary objective (19-21). They derive their rationale from studies which have shown that many individuals lack basic knowledge about dental diseases and their prevention. For example, Markula et al.(22) conducted a national study in Finland to ascertain levels of knowledge of periodontal disease and report that less than 50 per cent of their sample of 1 063 persons knew that loose teeth were indicative of periodontal problems and 45 per cent believed that eating fibrous foods would cure gingivitis. On the basis of a related study of a stratified sample of 732 persons, Murtomaa and Ainamo (23) concluded that many Finns were unaware of their own periodontal disease. Studies of children have reported similar findings. In a study of 14-year-old school children in England, only 6 per cent knew the meaning of the term gingivitis and only 11 per cent could define the term oral hygiene (24). More recently, Walsh (25) assessed the dental knowledge of 12- to 14-year-olds in San Francisco. In a test consisting of ten questions about disease and prevention, fewer than 50 per cent answered correctly on eight. Only 44 per cent knew that gingivitis is caused by plaque, only 25 per cent knew that periodontal disease is a major cause of tooth loss in adults and only 4 per cent knew the purpose of flossing. Similar deficiencies in dental knowledge have been reported in a Canadian survey of school children (26). Only two out of seven dental knowledge questions were answered correctly by more than 60 per cent of a national sample of those aged nine years. A sample of children aged 12 did somewhat better but none of the three questions asked was answered correctly by more than 75 per cent.

These studies suggest that people do not undertake preventive oral health practices because they are unaware of the need for brushing and flossing or lack requisite skills; hence, the stress on providing information about disease processes and their relationship to oral hygiene practices. However, while this approach has often been successful in improving knowledge and skills, improvements in oral hygiene behaviours have been more difficult to attain (27,28). Significant changes in oral health behaviours, or health indicators such as plaque and gingivitis, have been observed as a result of some programs but improvements have been short term and largely disappear after the dental health intervention has been terminated (29-31).

Recent studies have tended to confirm these findings. Walsh (25) reports significant improvements in the dental knowledge of an experimental group of 12- to 14-year-olds following a classroom health education program provided by dental hygienists. No such improvements were observed in a control group. No clinical examinations of either experimental or control groups were undertaken so the extent of behaviour change was measured using reported dental health care practices. No significant changes in reported practices were observed either within or between groups. Essentially similar outcomes have been reported by Albino et al.(32) and Melsen et al.(33). Even those programs in which information giving was supplemented by the teaching of practical oral health skills have been no more effective than information alone. Nikias (34) has reviewed five controlled studies of a packaged curriculum in dental health education developed specifically for elementary grades, all of which demonstrated that the combination of factual information and skill development did not improve oral health. Horowitz et al.(35) secured improvements in oral hygiene in children participating in a supervised daily plaque removal program but the differences in plaque levels and gingivitis scores disappeared during holidays when the children were away from school.

A conclusion often drawn from these studies is that repeated contacts and repetition of health education programs are necessary to secure longer term adherence to newly acquired behaviours (36-38). However, studies using repetition have produced conflicting results. Following the failure of an intervention using a single health education session (39), Tan et al.(40) assessed the effect of repeated dental care education of volunteers at the Dutch Royal Military Academy. Three chairside health education sessions undertaken by hygienists produced significant and relevent improvements in dental knowledge, attitudes and reported behaviour in an experimental group. These changes were maintained six months after the completion of the intervention. A control group showed no such improvement. It should be noted that all participants in the experiment were volunteers, of high socio-economic status and lived in a closed and highly disciplined environment. Consequently, these results may not be generalizable. For example, Agerbaek et al.(41) report that forthnightly 20-minute health-education sessions undertaken with small groups of 11- to 13-year-old Danish school children had little effect. There were no significant differences between experimental and control groups in terms of caries increments, gingivitis or dental knowledge.

The above studies confirm that increasing dental knowledge does not, in and of itself, lead to sustained behaviour change: knowledge is a necessary but not a sufficient factor in changing oral health practices (42). Based on the assumption that the problem is a lack of motivation, behavioural strategies which use positive reinforcement in the form of social and/or material rewards have been employed to promote the adoption of optimal oral health behaviours. The practical application of these behaviour modification techniques in preventive dental practice has been described by Weinstein and Getz (43) and Weinstein, Getz and Milgrom (44). Systematic research which demonstrates the effectiveness of positive reinforcement is limited but does suggest rewards may be effective in changing oral health behaviours. For example, Martens et al.(45) report sustained reductions in plaque scores in a group of Grade 2 children as a result of an instructional program which used positive reinforcement in the form of tokens which could be exchanged for toys. Plaque index scores were compared for 169 children in six classes comprising the experimental group and six classes (n=162) comprising the controls. Six months after completion of the program the scores of the experimental group remained significantly lower than those of the controls. However, the program to which the children were subject was complex and involved discovery learning, individualized interaction with a dental hygienist, personalized instruction and parental participation, as well as the provision of rewards. Consequently, the contribution made by positive reinforcement is difficult to assess. Studies by Albino et al.(32,46) also used positive reinforcement as part of school-based educational interventions. Again, the concurrent use of other motivational techniques mean that the effectiveness of rewards cannot be determined independently.

The combined effects of education and rewards on a group of adult patients has been reported by Iwata and Beckford (47). These patients had enrolled in a private practice-based oral hygiene program costing $80 (and might therefore be considered to be motivated). Patients were divided into two groups. One group received a standard educational program involving plaque control techniques while the other received an identical program plus an incentive; their treatment would cost up to 25 per cent less if their plaque scores declined substantially. At the final visit both groups had lower plaque scores than prior to the program. However, the fee reduction group showed a greater improvement in oral hygiene and this was maintained over the following six months. This was not the case for the program-only group whose scores had returned to baseline at the six-month follow-up.

Similarly, Lund et al.(48) report that such behavioural strategies were superior to informational approaches in stimulating the participation of Grade 7 students in a school-based topical fluoride program, while Kegeles et al.(49) report a similar effect on participation in short-term compliance with a home-based mouthrinse program. However, Lund and Kegeles (50) were not able to ensure long-term adherence to the program; rewards were effective in initiating the behaviour but, once they were withdrawn, such extrinsic motivation proved to be temporary and the practice was not maintained.

Strategies based on the provision of rewards can be expensive, particularly if, as it currently appears, they have to be maintained over time to attain longer-term compliance. For this reason they are probably limited in their appeal to educators and general practitioners. Kegeles et al.(49) have suggested that self-reinforcement and self-monitoring techniques might be used to reduce the input of rewards and to stimulate longer-term effects. Self-reinforcement means that patients reward themselves with an activity or event they enjoy once goals concerning preventive care or oral health are attained. Self-monitoring involves the patient in observing and recording his/her own behaviour, perhaps using a specially-designed chart that is returned to program personnel periodically. While Weinstein and Getz have described the use of such techniques within private dental practice, very little evaluative research has looked at their effects. The literature summarized by Kent, for example, is restricted to case reports (51) although non-dental studies suggest that self-monitoring is a useful approach to behaviour change (52).

Approaches which stress cognitive influences on oral health behaviours see values, attitudes and beliefs as the critical factors influencing the adoption of preventive behaviours. Persuasive communications are as much concerned with changing attitudes and beliefs as with the provision of technical knowledge and skills. The approach derives its theoretical basis from the Health Belief Model developed by Hochbaum, Kegeles and Rosenstock (53) to explain preventive dental behaviours. This model suggests that individuals adopt such behaviours only if three conditions are met: 1) they believe themselves to be susceptible to dental disease; 2) they believe dental diseases to be serious enough to interfere with some aspect of their lives; 3) they believe dental disease can be prevented and that prevention involves less economic and psychological costs than the diseases themselves. Following a review of studies based on the Health Belief Model, Haefner (54) concluded that perceived susceptibility was not a good predictor of preventive dental health behaviour. One study did find that people reporting high susceptibility made more preventive dental visits than people with low levels of perceived susceptibility, although other variables such as income, education and past preventive behaviour were more strongly associated with the dependent variable (55). A recent study using an experimental design sought to determine whether health beliefs predicted preventive dental behaviour and whether such beliefs could be changed by health education. The Health Belief Model did not predict the relationship between beliefs and preventive behaviour, nor did beliefs change as a result of dental health education (56).

Approaches which draw wittingly or unwittingly on the Health Belief Model concern the role of fear arousal, peer influence and health locus of control in the adoption of preventive oral health practices. One research team studied the effects of fear arousal on five groups of high school students. Four groups were presented with a standard set of instructions regarding brushing, flossing and disclosure of plaque. In three of the four groups, this information was preceded by communications containing high fear, low fear or positive messages concerning dental health. The fourth group received no supplementary message and the fifth group received no message but a more elaborate set of oral hygiene instructions. A plaque index, measured before and after the intervention, showed that the groups receiving positive messages and elaborate instructions showed the greatest improvement, but the effects for all groups disappeared after six weeks (57). A more limited experimental study also noted no differences between groups subject to fear appeals, positive messages or visual feedback of progress in oral hygiene (58). Studies which have demonstrated an effect from fear arousal tend to be inconsistent. The early work of Janis and Feshback (59) concluded that mild fear appeals were most effective, while Haefner (60), using the same communications, found that strong fear appeals had the greatest effect. Consequently, on the basis of available research, the role of fear in motivating preventive dental behaviour remains inconclusive.

Another approach attempting to change attitudes makes use of peer group influences. These are more properly regarded as micro-social influences, although, for convenience, they are included here. The aim is to enhance the perceived desirability and value of preventive dental behaviours by mobilizing social support for such actions. Adelson and Fischer (61) report that peers presenting dental hygiene information in televised dental education programs produced greater recall and comprehension than programs not using peer presenters. However, the effect on behaviour or oral health was not tested. The studies by Kegeles et al.(49) and Lund et al.(48) found that positive reinforcement was better than peer group influences in stimulating participation in preventive programs, while other studies did not include control groups in their evaluations of effectiveness (62,63), or used a combination of educational interventions which mean that the independent effects of peer support cannot be determined (64). An Australian study has reported a significant effect of using peers as role models even in the absence of oral hygiene instruction, although the groups studied were small and long-term follow-up was not undertaken (65).

Investigators of the relationships between health locus of control and preventive dental behaviours have produced no consistent associations. The health locus of control reflects an individual's belief in his/her own ability to determine oral health. While Beck and Lund (66) report significant correlations with reports of flossing, most of the medical and dental studies reviewed by Wallston and Wallston (67) found no association between locus of control and health behaviours. Since locus of control refers to a personality attribute, it probably presents limited avenues for producing behaviour change by means of health education interventions.

A more complex approach to changing human behaviour, one which combines many of the elements of the strategies just discussed, is to be found in social learning theory (SLT). This approach, recently adopted by a number of researchers in the United States, presents a broader theoretical scheme integrating behavioural, cognitive and environmental variables (68). SLT is particularly applicable to routine, repetitive behaviours such as oral hygiene practices. It identifies feelings of self-efficacy and expectations for success as important variables in the initiation and maintenance of preventive health behaviours. These involve convictions about one's personal ability to undertake brushing and flossing correctly and beliefs that these activities promote oral health. Knowledge and technical skills and environmental cues and supports are also important components of the model (69).

Preliminary studies using SLT have been reported by Tedesco et al.(70) and McCaul et al.(71). Tedesco and colleagues used phase-contrast microscopy to enhance traditional oral hygiene instruction with patients undergoing periodontal therapy. By providing powerful verbal and visual images of pathogens taken from diseased sites, it was hoped to bring about a change in patient's beliefs and attitudes concerning periodontal disease and its prevention. Pilot studies using small groups of patients indicate important gains in awareness, plaque control and gingival inflammation. Because control groups were not used, it is not possible to separate the effects of this technique from the total periodontal treatment package received by these patients. In addition, assessments were not carried out over the long term.

The studies by Tedesco et al. have more in common with the informational and cognitive approaches previously discussed. McCaul et al.(71) draw more comprehensively on social learning theory in order to develop predictors of brushing and flossing behaviour in young adults. These involved knowledge and skills, efficacy and outcome expectations and environmental influences such as barriers to oral hygiene practices and the behaviour of significant others, e.g. parents, spouse or roommates. Two variables, expectations and environmental influences, showed consistent relationships with preventive dental behaviours, predicting retrospective reports of brushing and flossing and self-monitored records of those behaviours. Consequently, McCaul et al. suggest that strategies for oral health should aim to increase efficacy and outcome expectations, decrease barriers to daily oral health activities and involve significant others in preventive routines. While this approach has much in common with the counselling techniques mentioned later, current evidence is insufficient to draw any firm conclusions regarding the utility and innovativeness of SLT in developing health interventions.

7.3 COMPLIANCE, SELF-CARE AND THE PATIENT-PRACTITIONER RELATIONSHIP

One problem most commonly encountered by dental care providers is poor patient compliance and poor motivation for oral self-care (72). This may be the reason why recent developments in dental health education are taking place within private practice (2). There is currently a measure of disagreement among both professionals and behavioural scientists about the likely effectiveness of these developments. Chambers (73) believes that practitioners are unlikely to be able to produce lasting behaviour changes in patients, and Sheiham (74) believes that a dentist/hygienist-centered strategy will not be effective in improving oral health at a community level. Evans (75) takes the opposite view and believes that self-management strategies offer excellent prospects for success in preventive dentistry. There remains a lack of data which can be used to substantiate either point of view. In the early 1970s, reviews of the literature by Young (21) and Corah (76) failed to find a single study related to the effectiveness of the time spent by practitioners in educating patients in oral hygiene. Since 1980, however, a number of studies have been published having a bearing on the issue.

Nikias (2) undertook a study of patients from nine private dental offices and the clinic of a school of dental hygiene, looking specifically at the outcome of practitioners' educational efforts. In the former setting, a plaque control program was provided by auxiliaries supervised by dentists, while in the latter, the same program was provided by student hygienists. Evaluation of patients' oral hygiene practices took place between five months and two years after instruction. Nikias claims that the study suggests that patient compliance is maintained over time and enhanced by feedback and reinforcement. However, because no assessments were undertaken prior to the program and because no control group was used, it is not possible to determine if behavioural change occurred as a result of the program. Two other practice-based studies, both reporting similarly favourable outcomes, also have methodological problems which make their findings difficult to interpret (77,78). A British study with a randomized controlled design reported essentially negative outcomes (79). Chairside dental health education of patients aged 11-13 produced some improvements in knowledge but these were not translated into behaviour or gains in oral health.

Unfortunately, perhaps, these four practice-based studies give no indication of the nature of the instructional programs offered to their subjects. Evidence from studies of medical practice indicates that information given in the context of medical encounters may be less well retained than information given during group instruction (80). This highlights the crucial role of the patient-practitioner relationship in health education and the association between compliance, communication and patient satisfaction.

In the medical literature it is now current to view non-compliance not as a failure of motivation on the part of the patient but as a failure of communication between patient and doctor. In fact, the term compliance, with its authoritarian overtones and image of the patient as a passive recipient of professional advice, has all but been abandoned. Increasingly, research is being focused on the nature and quality of communication between practitioner and patient and the positive outcomes of improving information exchange.

Poor communication has been ascribed to negative professional attitudes to information giving (81), "bureaucratic-task oriented" rather than "person" oriented interviewing styles (82), failures of comprehension and memory provoked by anxiety (80) and rejection of professional advice because it does not make sense to patients in terms of their own knowledge and experience of health and illness (83). The limited research available suggests that dentist-patient relationships are also characterized by poor communication. Rayner (84) notes that verbal interaction between dentists and patients is minimal and Linn (85) reports that almost two-thirds of patients never ask anyone for advice in the dental office, assuming the dentists will tell them what they need to know. Even where information is given, it may not be conveyed in an appropriate manner. Gold (86) notes that many dentists who tell their patients about plaque control are unaware that how they are relating is more important than what they are relating to patients. Motivating involves showing concern, eliciting and listening to the patient's own needs and goals and addressing the patient's perceptions of and ideas about his/her dental problems. Failures in communication will occur where the practitioner is distant, formal, controlling and talks at rather than with the patient. Studies of medical practice have found that where communication is poor, non-compliance increases substantially (87). Davis (88) found that low compliance was associated with doctors who did not seek the participation of the patient in the interview and gathered information without feedback to the patient. A more recent study of 140 consultations found that patient-centered interviews in which patients' views and opinions were discussed increased compliance significantly (89). Improved communications are part of the self-care approach to dental health education advocated by Weinstein et al.(90) and integral to counselling approaches to oral hygiene and dietary modification (91,92).

A study which demonstrates the benefits of a more patient-centered orientation to dental health education has been reported by Schou (93). Schou used a dental health education program based on active involvement characterized by the following principles. Teaching was carried out in pre-existing peer groups of 5-7 persons in order to create a familiar and relaxed atmosphere for the program. The teacher did not prepare a complete teaching package but planned the content of each session in discussion with the participants. This allowed the participants' own needs and goals to be included. Anxiety and economic liability, common dentist-patient barriers, were avoided by eliminating treatment from the program and providing it free of charge. Traditional dentist-patient roles were changed; the teacher-dentist avoided the expert role and victim-blaming type behaviour and encouraged subjects to exchange their own experiences. Finally, the health education sessions were repeated at monthly intervals for five months. Experimental and control groups were from among unskilled factory workers. Measures of plaque, gingivitis, dental knowledge and attitudes were taken prior to the start of the educational program and at intervals up to three and a half years after its termination.

The results indicate that the plaque index of the experimental group was significantly reduced three and a half years after the completion of the program and was significantly smaller than in the control group. Similarly, the gingivitis index in the experimental group was significantly lower than baseline at long-term follow-up, while virtually no change was observed in the control group. Further, there was a significant improvement in the dental knowledge of the experimental group six months after completion of the health education sessions which was not observed among the controls. While Schou's research focused on small groups which probably introduced a peer support component into the program, it seems apparent that the changed nature of the dentist-participant relationship and the style of communication that took place were key aspects of the approach.

The application of behaviour modification techniques within the practitioner-patient relationship is often termed counselling. This differs in two important ways from the more traditional methods of health education summarized above. Firstly, patients must actively participate in the learning process and secondly, emphasis is placed on working through the patients' present attitudes and habits rather than imposing attitudes and habits the professional feels are more appropriate (91). Counselling techniques can be applied to both oral hygiene practices (94) and dietary modification (92).

Based on the observation that most people brush their teeth as part of the activities of daily living, Weinstein et al.(90) advocate that counselling and behaviour-modification techniques be used within a self-care approach in which the aim is to enhance the patient's current oral hygiene practices. The program they describe combines most of the elements that feature in the health education and communication studies previously reviewed. It includes skill training, an understanding of personal factors affecting the individual's ability or willingness to change, the specification of long-term goals and short-term objectives, the use of positive reinforcement and self-monitoring techniques and the maintenance of newly acquired habits by follow-up.

However, plaque control endeavours cannot be personalized until a relationship has been established with the patient, and the practitioner has become aware of the individual's needs and goals. Moreover, it takes time for the individual to develop an awareness that he/she has a problem and for a desire for change to emerge. If plaque control remains the practitioner's concern and a patient denies "ownership" of the problem or is not ready to change self-care habits, then there is little that can be done. Work by Starfield et al.(95) supports this view. They found that patient-practitioner agreement about a problem was associated with better health outcomes than when the problem was perceived by the practitioner alone.

There have been, as yet, few rigorous evaluations of counselling and behaviour modification techniques in dental practice other than reports of the outcome of dietary counselling (92). In fact, there are few current studies of the dental provider-patient relationship or communication in dental practice. Most studies have focused on fear and anxiety and the attitudes of either patients or practitioners (96). Yet reviews by Garrity (97) and Wills (98) provide evidence from medical practice that the patient-practitioner relationship affects both clinical and behavioural outcomes. It is highly likely that this is also applicable to the practice of dentistry, although the necessary research to establish principles has yet to be undertaken.

7.4 CONCLUSIONS

The enormous literature on dental health education has so far failed to produce consistent scientific evidence of the benefits of any of the approaches currently employed. None of the knowledge, behavioural or cognitive variables investigated appears to explain or predict long-term adherence to positive oral health practices. The research is inconsistent and inconclusive and, where effects have been noted, they have generally been short-term, largely disappearing following cessation of the chosen intervention. One of the major limitations of this body of research is a lack of rigor in methodology and reporting. When Freed and Mathias reviewed 36 evaluative studies published between 1971 and 1975, they found major deficiencies in design (99). These problems persist in some studies published in the 1980s. Furthermore, some of the approaches beginning to be used have hardly been evaluated at all. Consequently, only tentative conclusions can be drawn from this literature and they must be regarded as suggestions rather than recommendations.

While these comments are somewhat pessimistic, the literature does at least provide grounds for optimism. It is clear from studies currently available that some dental health education interventions work for some people some of the time and can produce longer-term outcomes. Unfortunately, it is not always clear why seemingly similar interventions have worked on some occasions but not on others. It could be due to variations in response among those comprising the target group or variations in the personnel and/or method of delivering the intervention. One possibility is that programs are successful when they are able to personalize dental health education, irrespective of whether they are offered in institutional or clinical settings. A further problem is that analyses of data are rarely taken beyond the level of the entire target group. It would be useful to know if some strategies were successful with sub-groups and the characteristics of those susceptible to various kinds of approach.

The two issues of variations in response and personalization point to a need for a greater awareness and understanding of the target audience of health education messages. Measuring levels of dental knowledge using ten-item questionnaires tells us very little about the perspective of target groups, for it gives no indication of how that information is used by individuals in understanding and decision making with regard to their own dental health and oral health care practices. Personalized interventions require that the needs and goals of the recipients are known to allow more effective targeting of preventive health measures. The use of marketing concepts in dental health has been suggested by Quelch (100) and Murphy, Cooper and Kehoe (101), concepts which are equally applicable to media campaigns, institutional programs and education provided in clinical practice. However, as Swinehart (102) stated, data on individuals' motives for adopting preventive dental health behaviours are currently lacking.

While the literature on patient-practitioner relationships suggests the need for a more personalized strategy, it is also the case that methods of reinforcing behaviours need to be identified in order to transform short-term adoption of oral care practices into long-term habits. That behavioural change has been observed as a result of educational efforts is encouraging; the challenge is to find ways of making oral hygiene measures part of the activities of daily living. Extending educational interventions over longer periods of time, withdrawing programs in stages, and providing "booster" sessions are recommended by Weinstein et al.(43) for clinical practice and might be applicable to institutional learning in schools.

One of the most common findings of research in dental health education is that interventions are more successful at improving knowledge than at changing behaviour. Such an outcome should be recognized as a valuable end in itself and programs effective in teaching individuals about oral disease should continue. Equipping people with a scientifically sound knowledge base might not result in immediate changes in behaviour but might have, as yet undocumented, spin-off effects. One study has shown that health education in schools can have such effects in filtering through to family members (103). Sheiham (74) has recently reaffirmed the need for such teaching to be part of an integrated health education curriculum and not presented as an isolated learning module. The American Dental Association, Health and Welfare Canada and provincial Ministries of Education have produced educational materials that could be used within such a curriculum

(104). There is evidence to suggest that an ongoing curriculum is more effective in stimulating long-term changes in oral hygiene practices (105). However, some studies have shown that not all schools provided with dental health education materials are willing to adopt the program as part of their regular curriculum (106). The attitudes of teachers are clearly important in deciding whether children gain access to health knowledge.

There is some evidence in the literature to support the view that dental health education programs which integrate elements of the approaches previously discussed are, on the whole, more successful than interventions which draw on a single approach. Craft et al.(107) have recently reported the long-term effectiveness of a teacher-mediated dental health education package which combined scientifically accurate messages with educational and behavioural science concepts. Although the package was only taught over a three-week period, it was based on parental involvement, pupils' participation, repetition and reinforcement. Significant improvements in oral health status, along with major gains in knowledge and positive changes in attitude, were maintained at long-term follow-up. This suggests that the individual components of composite strategies may be mutually reinforcing and produce better outcomes.

The need for integration can also be applied to the various settings in which dental health education is undertaken; namely, the home, school (or work-setting) and dental practice. A comprehensive and coordinated strategy in which different objectives (each likely to be attained by a different type of intervention) are pursued in each setting, has yet to be tried. This should begin with new mothers to ensure that the informal learning taking place within the family instills in the child acceptable oral health practices. Schools and dental practices might then build on this basis by providing the knowledge, skills and motivation for long-term preventive health behaviours.

7.5 SUGGESTIONS FOR DENTAL HEALTH EDUCATION

1. Efforts to increase levels of knowledge of dental disease and oral hygiene practices should continue, irrespective of the immediate effect on behaviour.

2. Dental health education in schools should be taught as part of an ongoing health education curriculum and not as an isolated module.

3. Where possible, efforts should be made to design comprehensive interventions involving the home, school (or workplace) and dental office.

4. Irrespective of the setting in which they are applied, health education programs should use a variety of strategies simultaneously.

5. Health education should be personalized, either through the content of messages, the mode of delivery of the program or participatory learning.

6. All programs should employ follow-ups and booster sessions in the attempt to maintain any positive outcomes achieved.

7.6 SUGGESTIONS FOR DENTAL HEALTH EDUCATION RESEARCH

1. More needs to be known about lay beliefs concerning dental disease and oral health practices.

2. Individuals' own needs and goals with respect to dental and oral health need to be identified.

3. Detailed studies of dentist/hygienist -patient interaction should be undertaken.

4. The relationship between practitioner-patient communication, patient satisfaction and compliance needs to be explored.

5. Counselling and behaviour modification techniques used in dental practice need to be evaluated.

6. Some effort should be directed towards identifying systematic variations among target populations in their response to various strategies and approaches.

7. The components of apparently successful interventions need to be identified and tested on other target groups.

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CHAPTER 8

CHAPTER 8

COMBINATIONS OF PREVENTIVE METHODS

B.A. Burt

Most accepted regimens for the prevention of oral diseases have been developed as isolated methods, and tested in clinical trials using varieties of the classical test group/control group design. This line of research has allowed the efficacy of specific preventive methods to be determined, and over the years has been invaluable in separating efficacious from useless or marginal methods.

But few people receive only one preventive regimen at a time. Water fluoridation, use of fluoride toothpaste, mouthrinsing with a fluoride solution, taking fluoride supplements, and professional preventive care from dentists and hygienists are all common in North America. Introduction of any one preventive method to an individual or community is nearly always done against this background of existing preventive regimens. The benefit from the introduced preventive method may not be of the same degree as that achieved when the method is applied in isolation, because additive benefits from preventive measures are not necessarily cumulative.

It is likely that many clinical trials, supposedly testing a single preventive regimen, in fact tested that regimen against a background of other preventives, either controlled (as when all participants are receiving fluoridated water) or uncontrolled (as when participants may be making variable use of fluoridated toothpaste at home during a trial of another caries preventive). It can in fact be argued that in modern conditions virtually all prevention is "combined" prevention in one form or another.

The purpose of this chapter is to review the evidence for combined application of preventive methods and to present recommendations for practitioners and public health administrators.

8.1 DENTAL CARIES

Fluorides in Fluoridated Areas

The incidence of caries in fluoridated areas is already low. Experimental clinical trials in such areas can result in percentage reductions that may look impressive but which turn out to be quite low in absolute terms. In public health, this raises the issue of cost-effectiveness: whether the cost of running the program is worth it in terms of carious lesions saved. Cost-effectiveness can be an issue for the private patient too, but it takes a different form. When the patient makes an informed choice on whether or not to pay for a procedure that is likely to produce minimal benefit, that is a decision on cost-effectiveness.

Professionally applied gels and solutions

The first technique developed for topical fluoride application was the "Knutson" technique of four sequential applications of sodium fluoride solution (1). A prophylaxis preceded the first application; the mode of action of the fluoride was assumed to be uptake by enamel to increase its resistance. Several early studies of this technique were carried out in fluoridated areas, but added cariostatic benefits were minimal (2,3,4).

Reported results from applying other topical fluoride agents in fluoridated areas are variable. The technique for applying 8-10 per cent stannous fluoride solution, developed by Muhler (5), was judged to provide clear benefits in a fluoridated area when applied at six-month intervals (6). These results, however, were not duplicated by others (7,8). Horowitz and Heifetz ensured the permanent residence of all participants in their Chattanooga study, and provided annual applications of 10 per cent stannous fluoride for 30 seconds and 8 per cent for four minutes. Horowitz and Heifetz found that the latter technique provided a 20.7 per cent (0.5 DMF surfaces) reduction in new lesions over three years. Given the time taken for a prophylaxis and fluoride application, these authors concluded that the minor benefits achieved were not worth the cost of administering a program of professional application of fluoride in fluoridated areas. This was one of the earliest examples of applying the concept of efficiency to public health programs.

Szwejda (9) reached similar conclusions in his study of professional application of fluorides in fluoridated areas. Szwejda's studies in Michigan included assessment of the effects of acidulated fluoride phosphate (APF; 1.23 per cent fluoride as sodium fluoride with 0.1M solution of orthophosphoric acid, pH 3.0-3.5) in fluoridated areas. Results generally were little better than with stannous fluoride (9,10).

Professional applications of APF gel were just one of several preventive techniques employed with children in the fluoridated community of Ypsilanti, Michigan (11,12). In this demonstration program, children received dental health education, prophylaxis and fluoride application, sealants, and necessary restorative treatment. Reductions in caries after three years were relatively high, but are likely to have been mostly due to the sealant because caries in the age group studied is predominantly a disease of pits and fissures. In any case, the study's design did not permit separating out the individual effects of the different procedures.

The National Preventive Dentistry Demonstration Program (NPDDP) was an extensive four-year study to compare the effects of various combinations of preventive regimens in both fluoridated and nonfluoridated communities. The findings from this project have provoked a lot of discussion because they have challenged a number of accepted preventive therapies (13). Some aspects of research design in the NPDDP are not entirely clear, and it is fair to say that the value of this important study is still being debated. The NPDDP did find that the mean benefits from the prophylaxis plus APF gel applications (1.23 per cent fluoride, four-minute application twice per year in conjunction with the prophylaxis) were less than 0.5 DMFS over the four years for children in the fluoridated areas. The broad 95 per cent confidence interval for the benefits in the Grade 5 cohort (1.9 surfaces to -0.6 surfaces in a graphic, the latter figure reported as 0.2 surfaces in the text) makes a summary assessment of benefits difficult. Percentage reductions are not reported in the NPDDP.

In summary, the rather sparse data available suggest that there is little extra benefit to be gained from the routine use of professionally applied topical fluoride gel and solutions in fluoridated areas.

Self-applied fluorides

The "brush-in" technique was developed in Indiana during the 1960s. In this procedure, groups applied a material called zircate (9.0 per cent stannous fluoride in a zirconium silicate prophylaxis paste) under supervision. In one evaluation, the material was tested among lifetime residents aged 6-14 in fluoridated Frankfort, Indiana (14). After three years, a saving of 1.25 DMF surfaces was demonstrated (24.7 per cent), slightly lower than was found in a parallel study in a nearby nonfluoridated community. An interesting feature of this report, not commented upon by the authors, was that the increment of caries in the control groups was almost the same (5.07 in the fluoridated community, 5.40 in the nonfluoridated). The "brush-in" technique has since been largely superseded by logistically simpler procedures.

A study in fluoridated Stickney, Illinois, demonstrated benefits over three years from application of topical APF gel during the first year plus regular weekly mouthrinsing with 0.2 per cent sodium fluoride solution (15). The APF gel was self-applied in custom-fitted trays; the children inserted the trays for ten minutes on each of five consecutive school days on three occasions during the year, approximately four months apart. Children in this regimen showed 30.3 per cent fewer DMF surfaces after three years when compared to controls, a reduction of 0.71 DMF surfaces in absolute terms. Given that professional time was taken in preparation of the customized mouthpieces, the cost-effectiveness of this procedure remains questionable in a fluoridated community. The authors note that use of mass-produced standardized mouthpieces would cut costs; they believe that if these trays produced the same results, then the procedure might be worthwhile. That proposition has not been tested.

The Stickney study had administrative problems which caused the APF applications to be abandoned after the first year, so it is difficult to determine their effect as distinct from the rinses and the fluoridated water (no doubt many children were using a fluoridated toothpaste at home too, so there is some "background noise" here). One finding of interest, however, was that the caries reduction in occlusal surfaces (32.5 per cent) was equal to that found on mesiodistal surfaces, an uncommon finding in fluoride studies. It is possible that the intensive application of concentrated fluoride affects fissure bacteria in a way that less concentrated fluoride does not (16), so the Stickney technique probably merits further consideration with today's pattern of development of caries being dominated by occlusal caries.

The gel-tray technique was employed in an earlier study (17) in a fluoridated community, in which children applied acidulated sodium fluoride (1.1 per cent, pH 4.5) to their teeth in custom-fitted trays for three minutes at a time, three times per week for three years. Reported benefits were 28.6 per cent (0.63 DMF surfaces), though these results were clouded by marked differences between the two examiners. In a later study using a similar technique (18), no apparent benefits were found in primary teeth. Again, caries experience in this fluoridated area was already so low that it is not surprising that no additional benefit could be detected from the vinyl-tray procedure.

In summary, data are insufficient to permit the conclusion that self-applied topical fluorides provide sufficient extra benefits in a fluoridated area to warrant their regular use. The intensive-application technique (five consecutive days on three occasions per year) merits further study.

Flouride mouthrinses

Only a few of the large number of trials of fluoride mouthrinses have been conducted in fluoridated areas. Results generally show that there are additional benefits to be derived from this procedure; relative benefits generally are similar to those found in non-fluoridated areas though absolute benefits are naturally lower. These results are summarized in Table 8.1.

The major question from these studies is that of cost-effectiveness in public health programs. Mouthrinse programs cost just as much to administer in fluoridated areas, but the returns in carious surfaces saved is lower. Cost-effectiveness techniques have not yet been sufficiently developed in dentistry to allow the definition of a "cut-off" point, below which program operation would become uneconomical, but a perusal of Table 8.1 suggests that returns on some programs in fluoridated areas are below program costs.

Hagglund's data showed that the introduction of weekly rinses with 0.2 per cent sodium fluoride in the naturally fluoridated area of Sundasen, Sweden, led to a sharp reduction in the number of restorations required (22). Data were not presented in a manner which allowed their inclusion in Table 8.1.

By contrast with the modest though mostly favourable results displayed in Table 8.1, the NPDDP reached negative conclusions about the effect of fluoride mouthrinsing in fluoridated communities. No significant benefits were reported in fluoridated areas (13). Percentage reductions could not be computed for this study because baseline data were given by age and DMFS increments were given by grade cohort.

In summary, the data generally support the achieving of modest additional benefits from the use of fluoride mouthrinses in fluoridated areas, though the NPDDP did not. Unresolved questions surround the cost-effectiveness of the regimen for public health programs.

TABLE 8.1

SUMMARIZED RESULTS OF STUDIES OF FLUORIDE MOUTHRINSES IN FLUORIDATED AREAS

Authors	Material	Age Group Studied	Duration	Per cent Reduction	DMFS Reduction
Radike *et al.* (19)	0.1% SnF2 daily	8-13	20 months	33.1* 43.3**	1.00 1.22
Driscoll *et al.* (20)	0.05% NaF daily	12	30 months	27.9* 49.7**	0.72 0.94
	0.2% NaF weekly	12	30 months	22.1* 55.0**	0.57 1.04
Kawall *et al.* (21)	0.2% NaF weekly	9	24 months	33.8	0.52
Bell *et al.* (13)	0.2% NaF weekly	Grades 1-2 Grade 5	48 months 24 months	not given*** not given***	0.29 0.03

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* First of two examiners
** Second of two examiners
*** Could not be determined from data given

Fluoridated toothpastes

Toothpastes containing around 1000 ppm of fluoride are used widely in many parts of the world as part of the home routines of oral hygiene. Indeed, many authorities accept this widespread use of fluoridated toothpastes as a major reason for the decline in dental caries among children in developed countries. Fluoridated toothpastes are recommended for home use in fluoridated as well as nonfluoridated areas. The principal action of fluoridated toothpastes is thought to be the enhancement of remineralization by the regular introduction of low-concentration fluorides into the oral cavity, where the fluoride is stored, and released when needed, from enamel, plaque, and saliva (23). This mechanism duplicates the topical action of fluoridated water. As well as providing a reservoir of fluoride ions for the defense reaction, it creates a "hostile environment" for cariogenic bacteria (24), implying several modes of action for low-concentration fluoride. The "hostile environment" referred to may take some time to develop, which is perhaps one reason that results of clinical trials with fluoridated toothpastes generally have given modest results, not easily related to the extensive global benefits now often ascribed to these products.

Few clinical trials with fluoridated toothpastes have been conducted in fluoridated areas. Table 8.2 summarizes their results. The study of Lind et al.(25,26) was in a naturally fluoridated area in Denmark; Peterson's study (27) was in a fluoridated community in North Dakota. The greater benefits found in the Danish study may have been related to its longer duration or to the higher concentration of fluoride tested. Peterson noted how the caries experience among control group children had declined considerably in comparison with another study conducted in the area ten years earlier.

The limited evidence shows that fluoridated toothpastes produce additional cariostatic benefits in fluoridated areas. Because the use of fluoridated toothpaste is widespread, culturally acceptable, and of low cost (zero cost to public health programs if the cost of their promotion is ascribed to the manufacturers), their use is recommended in fluoridated areas.

Prophylaxis pastes containing fluoride

There have been few studies of the efficacy of fluoridated prophylaxis pastes in preventing caries, probably because it was recognized early that they were not in themselves a substitute for a professional application of fluoride. One study in fluoridated Fargo, North Dakota, found only slight and statistically non-significant benefits from the annual application of an APF/pumice prophylaxis paste over two years (28).

Where a prophylaxis paste is to be used, it should contain fluoride, but the use of such a paste as a preventive procedure by itself is not scientifically supported. That recommendation applies both in fluoridated and in non-fluoridated areas.

Other Combinations of Fluorides

The variety of ways in which fluoride delivers its cariostatic benefits makes combined procedures a conceptually valid way to maximize these benefits. Several combinations of fluorides have been tested in non-fluoridated areas. These combinations are systemic/topical, or using different concentrations and frequency of application of topical fluorides. Not all studies have used designs that permit the individual effects of the various fluoride components to be individually assessed. In addition, the unsupervised use of fluoride supplements at home has probably confounded the results of other studies trying to measure the effects of fluoride regimens (29,30).

Fluoride supplements and topical fluorides

In 1972, the United States Public Health Service began a project in rural Nelson County, Virginia, to assess the combined benefits of systemic and topical fluorides. Participating elementary schoolchildren consumed an APF fluoride tablet daily in school (1.0 mg of fluoride), rinsed weekly with 0.2 per cent sodium fluoride solution, and received a fluoridated toothpaste (1000 ppm fluoride) and

TABLE 8.2

SUMMARIZED RESULTS OF TRIALS OF FLUORIDATED TOOTHPASTE IN FLUORIDATED AREAS

Authors	Material	Age Group Studied	Duration	Per cent Reduction	DMFS Reduction
Lind et al. (25,26)	2.0% MFP	8 years	36 months	25.3	1.01
		11 years	36 months	36.4	2.63
Peterson (27))	0.76% MFP	8-12 years	31 months	20.1	0.64

toothbrushes for unsupervised home use. By 1980, the DMFS values for 12 year-old children had decreased from the 1972 level of 8.73 to 5.26, a 39.8 per cent reduction (31), and reductions in other age groups between 6 and 14 were of comparable levels. For the whole 6-14 age group, mean DMFS values decreased 49 per cent between 1972 and 1980.

Difficulties with interpreting the Nelson County results relate to the absence of concurrent controls and the inability to assess the effects of the individual components. Although the authors present analyses to defend the validity of the retrospective design, there are still inherent limitations in such studies. While there is no serious doubt that the fluoride regimens were a major factor in the decreases in caries registered, the fact that the study was conducted during a period of generalized decline in caries weakens its conclusions. Data from the NPDDP emphasize the difficulties of retrospective study designs during this period of caries decline (32); the NPDDP itself could ascribe little extra benefit to the use of fluoride supplements in addition to the other regimens employed (13).

In summary, little data exist on the additional benefits to be derived from use of a fluoride supplement in addition to various topical procedures, and it is difficult to interpret those that do.

Fluoride mouthrinses and toothpastes

This combination is of particular interest because it is one that many people are using. Fluoride mouthrinsing is a feature of many public health programs. Proprietary fluoride mouthrinses are available over the counter in the United States and Canada, and the use of fluoride toothpaste is almost ubiquitous. The other special point of interest is that both methods employ the same mechanism of fluoride action, that is the regular introduction of low-concentration fluoride into the oral cavity to promote remineralization and inhibit glycolysis (33) through uptake by enamel, plaque and saliva. The regular introduction of low-concentration fluoride into the oral cavity is now thought to be the most effective method of using fluoride (34), so it is a good question to determine if there are additive benefits from rinsing and brushing.

Results of trials that have compared rinsing and toothbrushing in various combinations are given in Table 8.3. All found some added benefits, but the rinse and toothpaste together did not give results that were clinically more impressive than those from either alone. The study of Ashley et al.(35) found that the two procedures resulted in 0.69 fewer DMF surfaces over two years, while Blinkhorn et al.(36) found effectively no difference. The study of Triol et al.(37) used a design that differed from that of the two British studies in that there was no placebo control; an MFP toothpaste group was compared to results from three concentrations of sodium fluoride rinse plus the toothpaste (only the results from the daily 0.05 per cent sodium fluoride rinse are shown in Table 8.3 for comparative purposes; results from the other two concentrations were similar). In this trial, the rinse plus toothpaste led to 0.70 fewer DMF surfaces compared to use of the toothpaste alone over 30 months. The Florida study of Ringelberg et al.(38) was primarily to compare the efficacy of amine fluorides and inorganic fluorides (no difference found), but did provide data comparable to the other studies, and indeed the results were generally similar. In this case, the rinse appeared more efficacious than the toothpaste and to both in combination, but toothpaste use was unsupervised.

One of the research groups suggested that results might have been better if the rinse had been conducted at a different time, rather than immediately after the brushing (36). All three studies used this same procedure. It is plausible that if regular introduction of low-concentration fluoride into the oral cavity is the regimen to be promoted, that doing both the brushing and rinsing together might underestimate the potential benefits of using both procedures.

In summary, the data from well-conducted clinical trials are consistent in showing only minor added benefits of fluoride rinsing with the use of a fluoride toothpaste. The data can hardly justify the promotion of programs of

TABLE 8.3

SUMMARIZED RESULTS OF STUDIES OF ADDITIVE EFFECTS OF FLUORIDE MOUTHRINSING AND SUPERVISED BRUSHING WITH FLUORIDATED TOOTHPASTES

			DMFS Increments			
Authors	Age Groups	Duration	F Rinse*	F Toothpaste**	Rinse+ Toothpaste***	Placebo
Ashley et al. (35)	Approx 13	24 months	4.81 (13.1%)****	4.44 (17.9%)****	4.12 (22.7%)****	5.61
Ringelberg et al. (38)	11	30 months	4.79 (23.4%)****	5.14 (17.8%)****	5.30 (15.2%)****	6.51
Triol et al. (37)	10-13	30 months	none	6.30	5.60 (11.1%)*****	none
Blinkorn et al. (36)	11-12	36 months	4.72 (24.5%)****	4.60 (26.3%)****	4.76 (26.8%)****	6.25

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* 0.05% NaF daily at school

** 0.76% sodium monofluorophosphate except for Ringelberg et al. (0.4% stannous fluoride, unsupervised)

*** all conducted supervised rinse immediately after brushing

**** percentage reduction compared to placebo control

***** percentage reduction compared to MFP toothpaste alone fluoride mouthrinsing in areas where fluoride toothpaste is being widely used; even if there is some clinical effectiveness, the program could hardly be cost-effective. Both procedures could be recommended, however, for those patients who have a problem with caries.

Fluoride varnishes with other fluorides

Studies on the efficacy of fluoride varnishes have given equivocal results (review 39). None of these studies has been conducted in fluoridated areas, but several recent studies have been conducted with children known to be receiving other caries-preventive programs. In a Finnish group of low caries incidence, Kolehmainen (40) found the varnish to increase fluoride concentration in enamel but to have little effect on caries experience. Children participating in the study of Clark et al.(41,42) in Sherbrooke-Lac Megantic, Quebec, were known to be using fluoride toothpastes at home. Some were taking fluoride supplements. Caries reductions were 0.5-0.7 permanent tooth surfaces and 0.2-0.6 primary tooth surfaces over 32 months, data which hardly support the use of fluoride varnish in public health programs and which question its routine use in private practice.

Other combinations of fluorides

The United States Navy conducted studies on its "three-agent" technique in the 1960s, a time when the benefits of stannous fluoride were first becoming known. This regimen employed a 17.5 per cent stannous fluoride prophylaxis paste followed by a professional topical application of 10 per cent stannous fluoride solution, with daily use of 0.4 per cent stannous fluoride toothpaste. Substantial reductions in caries were reported, and the use of the three agents was more beneficial than use of one or two (43). This basic technique (professional prophylaxis and topical fluoride application and use of fluoride toothpaste) is in wide use today, though other formulations have largely replaced stannous fluoride in these products.

APF gel has been tested in combination with a mouthrinse in one study, and with a toothpaste in another. Mainwaring and Naylor (44) found that unsupervised use of the MFP/calcium carbonate toothpaste was just as efficacious as APF applications twice per year, or both together. By contrast, DePaola et al.(45) found better results with combined use of gel and mouthrinse when compared to either used alone. However, the gel was used in a self-application technique for ten consecutive days, intensive use that could have marked bactericidal effects and which was similar to that used in the Stickney study (15). Unfortunately there were logistical problems reported with this intensive self-application of the gel; the authors consider the technique unsuitable for public health use.

High-intensity use of multiple fluoride vehicles has proved successful in controlling caries in those patients who have received irradiation treatment for cancer of the head or neck (46,47). The xerostomia resulting from this treatment renders the patient highly susceptible to caries. Professional gel applications, self-applications of gel, mouthrinsing and use of fluoridated toothpaste have all been employed, a "shotgun" approach that would be excessive in the average person but which is called for in this group of patients.

From these studies, the regular use of high-concentration gel with low-concentration toothpaste or rinse seems unlikely to provide additional benefits for most patients, even though such regimens are known to be widely employed and are frequently recommended (48). The data do not support the use of gels in most public health programs. Intensive use of the gel is likely to be effective with highly susceptible patients, where all possible mechanisms of fluoride's action need to be employed.

Fissure Sealants in Fluoridated Areas

A large number of studies, considered earlier in Chapter 3, have demonstrated the clinical efficacy of fissure sealants. Some of these studies have been carried out in fluoridated areas. The results show that sealants are equally efficacious in fluoridated and non-fluoridated areas. In the NPDDP, where sealants were applied in all geographic sites, both fluoridated and non-fluoridated, success rates were similar. In the non-fluoridated areas, children in the grades 1 and 2 cohort had a slightly higher number of DMF surfaces saved than did those in the fluoridated areas, but this situation was reversed for children in the grade 5 cohort. There the savings in the fluoridated area averaged 2.00 surfaces per child over the four years of study, compated to 1.11 surfaces saved in the non-fluoridated areas (13). Sealants were seen to be the main reason for reductions in caries in the multi-procedure preventive demonstration of Bagramian et al. in the fluoridated community of Ypsilanti, Michigan (11,12,49).

Issues related to efficacy of sealants are unrelated to the status of fluoridation of the community. Because the rates of caries in fluoridated communities are usually lower than in non-fluoridated communities, there can be a cost-effectiveness question regarding sealant use in public health programs. This issue is far from clear-cut at present, and has been discussed in detail elsewhere (50,51). Public health administrators needing to make a decision on whether to operate a sealant program or not, should consider the overall rates of caries, proportion of lesions in pit-and-fissures, resources and political factors. If a sealant program is commenced, data should be kept on costs as well as effectiveness for program evaluation.

Fissure Sealants and Topical Fluorides in Non-fluoridated Areas

Sealants and topical fluorides appear to be complementary procedures; fluorides have their principal effects on smooth and proximal surfaces while sealants prevent caries in pit-and-fissure surfaces. With topical fluorides in widespread use in North America, sealants seem a logical preventive method to combine with use of topical fluorides. But while few would argue with this contention, evidence to support it is not yet strong.

Apart from the NPDDP (13), only two studies have assessed the combined use of sealants and topical fluorides in a non-fluoridated area, and neither permitted the individual effects of the fluoride and sealant to be separated. Rantala (52) analyzed data from the school dental service in Finland and concluded that the proportion of caries-free first molars in children aged 7-9 years rose from 50 per cent to 81 per cent in the two years after the use of sealants was added to the application of two per cent sodium fluoride gel. But the absence of concurrent controls in this retrospective analysis makes it difficult to ascribe all the benefits to the preventive programs, especially as the same report describes success with preschool prevention. Low (53) used a half-mouth technique to demonstrate caries-preventive benefits from combined use of a fissure sealant and eight per cent stannous fluoride applied to the etched fissures, but again the combined benefits could not be separated from the benefits to be achieved from the use of either technique alone.

The likely complementary effect of sealants and topical fluorides does not necessarily mean that topical fluorides should be added to sealant use in public health programs, for the combined effects are certainly less than additive (13). In addition, there is the existing effect of the fluoride "background" (discussed at the beginning of this chapter), which means that most North Americans are already receiving topical fluoride in some form. Given the poor additional benefits from use of two fluoride vehicles which act in similar manner, such as mouthrinse and toothpaste described earlier, addition of topical fluorides to a sealant program would not be justified on grounds of cost-effectiveness in communities where prevalence of caries is moderate to low. Most patients being treated with sealants in the practitioner's office would benefit little from additional fluoride (assuming they are also using fluoridated toothpaste), unless they had an unusual number of smooth surface lesions. As stated in the previous section, there is more to be learned about additive effects of sealant and fluoride.

Professional Oral Hygiene and Fluoride Regimens

Intensive professionally administered procedures of oral hygiene, including use of fluoride prophylaxis paste and toothpaste, have been shown to reduce caries increment dramatically under certain conditions. The series of reports known as the Karlstad studies described a regimen of frequent (two-weekly for two years, extended to eight weeks in older children after their initial two years) and intensive "oral cleanings", allied to an educational program on dental health which included the families as well as the children (54). The reported degree of caries reduction has been greeted with some skepticism by some observers; others have suggested that results were as attributable to the fluoride being used as they were to the oral hygiene per se.

To answer these criticisms, the Karlstad researchers conducted a study to compare the effects of the regimen with and without fluoride. The control group received the standard oral cleaning, including fluoride prophylaxis paste and fluoride toothpaste, while the test group received the same cleaning and educational regimen though with non-fluoridated prophylaxis paste and toothpaste. At the end of the year, no significant differences in new carious lesions (or gingival inflammation and plaque deposits) were reported (55). But there are some limitations in this study which weaken its conclusions. Group sizes were small enough that quite large mean differences would have been required to demonstrate statistical significance. As it was, the test group averaged 0.70 new carious surfaces compared to 0.26 in the control group, and much of this difference was attributed to one child who had an unusually large number of new lesions. In addition, one year is too short a time to conduct a caries trial. The impressive results achieved by the Karlstad researchers can still be attributed to the mixture of oral hygiene, fluoride and intensive dental health education. Replications of the Karlstad regimen by others (56,57,58,59,60) have produced more modest caries reductions.

A more recent study from Sweden compared and contrasted the effects of the Karlstad-type oral cleaning, diet and oral hygiene instruction, professional topical fluoride and sealing among children who were already in a two-weekly fluoride rinse program (61). All regimens registered caries reductions relative to controls, but the validity of the findings is questionned by one group's apparent longitudinal reduction in proximal caries. This finding was attributed to the arrest and reversal of caries, but the addition of two new examiners to the study over its five years at least raises the possibility that the result was due to differences among examiners.

The Karlstad studies did seem to make the point that meticulous oral hygiene enhanced the benefits from fluoride therapy. But even that seems at odds with both current views on how fluoride works (33), and with the results of studies which showed that the traditional prophylaxis prior to professional application of fluoride added no benefits to the fluoride application (62,63). A Finnish study on the relationship between sugar consumption, toothbrushing and dental caries in fluoridated and non-fluoridated areas led to the suggestion that plaque may serve the function of introducing more fluoride to the tooth surface (64).

In summary, the appropriate degree of oral cleanliness to maximize the benefits of fluoride has not been determined. Any hint that some plaque might be "good" seems to oppose one of dentistry's cornerstones, but the evidence does suggest that plaque has some active role in the anti-caries defense mechanism. This must not be taken to suggest that plaque accumulation in the oral cavity can ever be encouraged. Plaque is not a standard entity, it is an ecological system which is constantly changing. Certain qualities of plaque have been identified with particular disease states, so it is possible that a particular quality and quantity of plaque might also be associated with conditions of oral health. Until such conditions are identified, however, the best possible degree of oral hygiene must be recommended. Oral hygiene should be encouraged predominantly for control of gingivitis, though there is some evidence presented in the next section to suggest that good oral hygiene is a contributory factor in the prevention of caries.

Oral Hygiene and Diet Control

A series of reviews which have examined the relationship between oral hygiene status and dental caries have reached equivocal conclusions (65-69). There is general agreement that excellent oral hygiene, where it can be achieved, will prevent new carious lesions, but there is also acceptance that personal oral hygiene practices usually do not reach these standards. The reviews were in general agreement that control of caries through oral hygiene alone is laborious and inefficient. But definition of the relationship between oral hygiene and caries is hampered by some inherent difficulties; cross-sectional studies are limited by the time differences between changes in oral hygiene status and caries development, and oral hygiene indexes are generally too crude to detect anything more than the most gross correlation. These inherent problems are the main reason for the equivocal nature of the reviews, despite the research attention that the subject has received.

There is some evidence that oral hygiene may be related to caries development, though in a multifactorial context rather than directly. Studies in Finland have suggested that caries progression is related to overall sugar consumption in children with poor oral hygiene, but not among children with good oral hygiene (70, 71). The practical implication of these findings could be that sugar intake among patients is of less importance where oral hygiene is good, but could be a major factor where oral hygiene is poor. Confirmatory studies on the triangular relationship between diet, oral hygiene and caries are lacking, and in North America would be seriously hampered by the near-universal use of fluoridated toothpaste and generally high consumption of sugar. There is nothing in the existing data, however, to contradict the recommendation that good oral hygiene should be encouraged as a contributory factor in caries control.

8.2 PERIODONTAL DISEASE

Control of periodontal disease is based upon preventing the build-up of bacterial plaque in the gingival crevice. This goal is achieved by personal oral hygiene and professional prophylaxes, the latter being supplemented where necessary by curettage and root planing, which in turn sometimes require light surgery to provide access. Antibiotic therapy, in conjunction with professional treatment, can be prescribed to control bacteria in the gingival crevice.

Prevention of periodontal disease uses much the same procedures and techniques as its treatment and control, and in a sense all prevention of the disease involves combined procedures. Personal oral hygiene requires instruction in techniques of toothbrushing and interdental cleaning, and it also seeks to tap that elusive entity called motivation. Instruction and education can be handled on an individual basis, and can also be a suitable subject for mass education. There is no firm evidence that dental health education of the public has led directly to improvements in oral health, but the subject is not easy to research.

Gingivitis is usually thought to be a necessary precursor of periodontitis, though this sequence has bever been conclusively demonstrated (72). Primary prevention of periodontal diseases, however, is usually aimed at preventing gingivitis, with personal oral hygiene practices being the main thrust. Combined preventive activities commonly include personal oral hygiene practices and associated instruction with regular professional cleaning. Chemotherapeutics in toothpastes and rinses can be expected to be increasingly used, because materials such as chlorhexidine, alexidine, stannous fluoride, and several cosmetic mouthrinses have received considerable research attention in recent years. Such materials are likely to be a regular part of the prevention of gingivitis in the future. For the present, however, only the Karlstad-type studies, combining professional and personal oral hygiene practices, have presented systematic study on combined approaches to preventing gingivitis.

8.3 DISCUSSION

Although combined procedures dominate the modern approach to prevention, most have not been well tested. Nor is it likely that they will be, in North America at least, because dental caries in children is no longer the public health priority it once was, and because such trials would require large numbers of participants and thus be highly expensive. Useful and relatively inexpensive information might come from selected retrospective analyses of existing data.

A major problem for administrators is determining the effectiveness of specific programs against the now-customary background of public health and individual prevention procedures. Because of the scarcity of experimental clinical trials which have specifically tested combinations of preventive regimens, policy and recommendations in many instances must be based upon inadequately controlled studies and even subjective estimates. The difficulties in determining efficacy of additional preventive procedures are compounded when public health administrators attempt to make decisions on efficiency of preventive programs, for little beyond theoretical considerations is available to guide such decisions.

Because of the time and expense of both efficacy trials of combined procedures and of cost-effectiveness trials, advances in knowledge on these issues probably will have to come from empirical evaluations of public health programs rather than from experimental studies. These evaluations can be extended to benefit packages in dental insurance programs, where policy decisions on what to include or not include must be made by carriers. Decisions on appropriate combinations of procedures could save purchasers large sums of premium dollars without compromising either the quality of care provided or the oral health of the purchasers.

What is clear from this review is that fluoride procedures are not simply cumulative in their effects, and that a "more is better" attitude does not apply to the use of fluoride. Where public water supplies are fluoridated and the public is making habitual use of fluoridated toothpastes, it is questionable if any further benefits accrue to most people from additional fluoride use. (Of course, there are always individual exceptions.) Where fluoridated water does not exist, fluoride supplements presumably join fluoride toothpaste as the "basic" form of caries prevention, but this combination has not been properly tested. Sealants and appropriate use of fluoride can theoretically almost end caries altogether, but the costs of such an exciting prospect are likely to be unacceptably high. The research challenge is still to determine the most economic combination of preventive procedures which will reduce caries to an irreducible minimum.

Primary prevention of gingivitis is based on the assumption that gingivitis is a necessary precursor of periodontitis. Combined preventive methods tested to date are various mechanical and educational means of achieving oral cleanliness, though chemotherapeutic rinses and toothpastes are being developed and tested. These products, when tested for efficacy in humans, should be so tested with different mechanical procedures of oral hygiene.

8.4 RECOMMENDATIONS

From what is frequently the limited data available, the following recommendations can be stated:

1. Professional applications of topical fluorides cannot be generally recommended in fluoridated areas, though they may benefit highly caries-susceptible individuals.

2. Modest additional benefits can be expected from fluoride mouthrinsing programs in fluoridated areas, but there are questions of cost-effectiveness in relation to the advisability of such programs.

3. Modest additional benefits can also be expected from the routine use of fluoride toothpastes in fluoridated areas, but since their use is already widespread and there are other benefits from regular procedures

of oral hygiene, their use should be recommended.

4. Self-applied gel-tray procedures cannot be recommended in fluoridated areas, though if a simple and inexpensive method of using the intensive consecutive-day approach can be devised, it might be cost-effective in some communities.

5. No recommendations can be given for public health use of fluoride supplements in addition to topical treatments, nor for public health use of fluoride prophylaxis pastes plus self-applied topical treatments.

6. Fluoride mouthrinsing adds only minor clinical benefits when added to programs of supervised toothbrushing and fluoride toothpaste, and cannot be recommended for public health programs on the grounds of cost-effectiveness.

7. Current data do not support the use of fluoride varnishes in areas where other preventive procedures are in use; additional benefits appear minor and cost-effectiveness is doubtful.

8. Sealants can be recommended in fluoridated areas, or for children receiving other caries-preventive benefits, on the grounds of added efficacy. Questions of cost-effectiveness can be addressed through evaluation of costs, benefits and practicality of such programs.

9. Intensive professional oral hygiene procedures, employing fluoride materials with professional cleaning and dental health education, are efficacious but unlikely to be cost-effective and can thus be recommended only for special groups.

10. Use of all of these combined procedures can be recommended for certain individual patients with caries problems, as well as for public health programs in communities where caries is a documented problem.

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CHAPTER 9

CHAPTER 9

PREVENTION OF TRAUMATIC ORAL INJURIES

P.M. Johnson

9.1 INTRODUCTION

Traumatic oral injuries arising from sports, motor vehicle and recreational accidents and accidents in the home are among the acute emergencies that may confront the dentist. Such injuries can be irreversible and costly in terms of repair and suffering.

Information on traumatic oral injuries and recommendations for their prevention, together with supporting documentation, were presented in the original report, Preventive Dental Services; Practices, Guidelines and Recommendations (1). This report reviews the earlier findings in light of more recent information. The focus of this section is on the effectiveness and efficiency of measures and strategies to prevent injuries to the intra-oral region. Readers wanting technical information on the fabrication and care of preventive devices or information on extra-oral injuries are referred to other sources.

Information on traumatic oral injuries and strategies for their prevention, while presently scanty, is increasing. Most published studies have investigated injuries sustained in organized sports such as hockey, football and rugby and are specific by age and position played. Compliance with the use of protective face and mouth guards in these sports is increasing. Less is known about the causes, prevalence and prevention of injuries that are not sports-related, many of which involve children. In addition, participation by individuals of all ages in a wide range of athletic activities suggests that preventive measures for persons other than players in leagues for contact sports should be of special concern. Appropriate studies are required to determine needs and priorities for protection and to identify cost-effective preventive measures.

An information base of potential assistance in the reduction of traumatic oral injuries is being developed in Canada. The Canadian Accident Injury Reporting and Evaluation (CAIRE) project was initiated in 1982 by the federal Department of Consumer and Corporate Affairs (4). Designed to generate information on accidental injuries involving consumer products (motor vehicles excepted), CAIRE's purpose is to assist organizations and agencies to establish priorities and to evaluate preventive programs. Currently, data are provided by five hospitals, including three children's hospitals, located across Canada. While the small sample size and bias towards children preclude generalization of the data, it will be possible to identify certain trends. These data, of course, will not reflect those casualties with oral injuries that are observed in private dental offices. CAIRE collects data on the nature and cause of injury, type of product and age group of the casualty. For dental health purposes, inclusion in the data bank of the actual intra-oral structure injured (for example, distinguishing between teeth and gums) would enhance its usefulness. This modification is achievable since the current data coding system (ICD-9N) includes the classification levels required to record this information. In summary, the CAIRE project is a good potential resource for investigating traumatic oral injuries and their prevention.

9.2 SPORTS AND ORAL INJURY

Traumatic oral injury associated with participation in sports is common. The head and, in particular, the mouth can be the most vulnerable and least protected areas of the body in sports, especially those involving body contact. Studies continue to demonstrate the benefit of wearing protective equipment, thereby reducing the frequency and severity of oral injuries sustained in football, hockey, soccer and rugby (5,6,13). A number of sources

TABLE 9.1

RECOMMENDATIONS FOR SPORT-RELATED USE OF EXTRA-ORAL FACE PROTECTORS AND INTRA-ORAL MOUTH AND TOOTH PROTECTORS*

	Type of Sport	Type of Protector
1.	Football, rugby	Both extra-oral face protector and intra-oral mouth protector.
2.	Hockey, lacrosse	Extra-oral face protector. Use intra-oral mouth protector for secondary protection.
3.	Baseball (catcher)	Extra-oral face protector.
4.	Other contact and some non-contact sports including: soccer, rugger, field hockey, cricket, basketball, wrestling, boxing, squash, handball and racquetball.	Intra-oral mouth protector.

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* Recommendations reflect current professional judgment for those applications for which empirical evidence is lacking.

are available on the design and fabrication of protective equipment (for example, see references 2,3,24,25).

Types of Mouth and Face Protectors

Two types of protection are available - the externally fitted or extra-oral face protector and the internally fitted or intra-oral mouth protector. Recommendations for the use of each type, as summarized in Table 9.1 and further described below, are dependent on the sport or activity involved and the specific protection required.

Extra-oral face protectors

Rationale for use -- Extra-oral protectors, commonly referred to as face masks or face guards, are intended to prevent injuries to the eyes, nose and oral structures. When used in football, face guards have resulted in a 50 per cent reduction in oral injuries; the combined use of face guards and intra-oral mouthguards has virtually eliminated oral injuries in this sport (7). A reduced rate of injury among hockey players has been reported -- 21 per cent for protected players versus 52 per cent for those not wearing face guards (5); these findings are consistent with those of a previous Canadian study (6).

Design -- Ideally made from a rigid, non-pliable material, face guards should be designed to fit various headshapes and sizes. Most face guards are fitted to helmets. The helmet must fit snugly at key pressure points to ensure that the face guard will remain properly positioned and not become dislodged or rotated during play. Oversized guards and helmets should not be bought with the thought that children will grow into them. Several models are available, specific to the sport and position played. The full face guard is recommended over the abbreviated visor-style for protection against oral injury. The moulded mask style associated with some hockey goal-keepers is less effective than the nylon-coated wire-mesh guard which is designed to prevent the penetration of hockey pucks and sticks. Guards which have a plastic eye visor inserted in the mesh shield are said to provide improved vision compared to all-mesh guards.

The Canadian Standards Association (CSA) has established criteria for the manufacture of CSA-approved helmets and face guards. All helmets sold in Canada must meet the CSA standard (8). The standard for face guards provides for full-coverage face protection for hockey players and for lacrosse players (9).

Use -- Players in the minor hockey division of the Canadian Amateur Hockey Association (CAHA) are required to wear a CSA-approved facial protector and helmet (10). Players in the junior and senior divisions (17 years and older) of the CAHA or in the professional hockey leagues are not required to wear facial protectors. However, apparently having accepted face guards as basic equipment during their younger playing years, many of these players continue to wear them. In all divisions of female hockey in the CAHA, a CSA-approved facial protector must be worn (10). While the Canadian Amateur Football Association does not mandate the use of face guards, it does recommend the use of helmets and specifically those approved by the National Operating Committee on Safety in Athletic Equipment (NOCSAE). Most of these helmets have face guards. The Canadian Dental Association recommends the use of rigid, fixed position (as opposed to readily detachable) face guards for players engaged in hockey, lacrosse, football, rugby and baseball (catcher position) (11).

New developments -- A distinctly Canadian achievement is Allan Average, a headform standardized to the dimensions of an average seven-year-old boy (12). Developed under the auspices of the Canadian Standards Association on a grant from the federal government, the headform will be used to develop and test protective equipment suitable for players five to ten years of age. Development of a second headform, sized to the average twelve-year-old boy and suitable for testing equipment for women, has been proposed.

Yet to be resolved is the question of whether helmets and face guards for young children should be proportionately lighter than helmets for youth and adults (in addition to the gain made through down-sizing) to reflect the differences in body weight and related impact forces. The purpose would be to reduce the hazards associated with unnecessary load on the neck and spine.

Intra-oral protectors

Rationale -- Intra-oral protectors, commonly called mouthguards, are usually designed to fit over the upper or maxillary teeth. They protect against three basic types of injury:

1) trauma to the soft tissue (lips, cheeks and gums);

2) trauma to the hard tissue (teeth and bone); and

3) concussion.

Trauma can be caused either directly by contact with an external object or indirectly by the accidental and forceful closure of the lower jaw or mandible. The mouthguard is purported to disperse external lateral blows, prevent forceful closure, and keep the teeth away from the lips. By preventing upward and backward displacement of the mandibular condyle and its articulating fossa, an event frequently associated with a blow to the chin, the mouthguard protects against concussion and other damage.

Design -- There are three basic types of mouthguards:

1) stock;

2) mouth-formed; and

3) custom-made.

The stock-type is prefabricated in standard sizes. Poorly adapted to most mouths, this type has many disadvantages, not the least of which is lack of adequate protection.

Mouth-formed protectors consist of two major types. One is a thermoplastic shell which, when softened in boiling water and inserted in the mouth, can be adapted to the teeth and gingiva (2). The procedure can be repeated as necessary over the lifetime of the protector. The other type is a preformed outer shell with a self-curing resin or silicone liner which is adapted to the oral structures. Irrespective of the type of mouth-formed protector selected, care should be taken to adapt the protector carefully in the labial and muco-buccal areas while avoiding unnecessary bulk.

The custom-fitted mouthguard usually is fitted by a dentist. It is fabricated from a thermoplastic material on a stone cast of the athlete's maxillary dentition and trimmed for maximum comfort and fit. While more expensive, the custom-fitted model generally is well accepted by athletes who report fewer problems with speech, breathing and taste (3,13).

Use -- Compliance with the use of mouthguards is higher than with face guards, due in part to their reduced conspicuousness. Considered a standard part of the equipment for contact sports such as boxing and football, mouthguards are recommended for use in any sport that might involve injury to the teeth and mouth area. The Canadian Dental Association recommends the use of mouthguards for players involved in football, soccer, rugby, rugger, basketball, field hockey, cricket, handball, waterpolo, wrestling, boxing, cycling, horseback riding, water skiing and a variety of racquet sports, including squash, tennis and racquetball (11). Their use in hockey and lacrosse is considered secondary to the use of face guards. The use of mouthguards while playing is mandatory under the Canadian Amateur Football Association rules, with the custom-fitted, rather than the stock-type mouthguard preferred.

Two precautions in the use of a mouthguard should be noted. Persons wearing orthodontic or other oral appliances or who have mouth malformations should wear internal protectors only under the supervision of a dentist. Also, children aged thirteen years and under have rapidly changing dentitions and should not wear mouthguards unless the fit is monitored regularly.

Combined use of protective measures

The combined use of an internal mouthguard and an external face guard provides maximum protection against injuries to the mouth and teeth. The initial cost is offset by the potential discomfort and expense associated with the restoration or replacement of injured teeth. The face guard protects against horizontal blows whereas the mouthguard protects against blows to the underside of the chin. The Canadian Dental Association recommends that both a fixed external face guard and a fitted internal mouthguard be worn by football and rugby players; their use is recommended for hockey and lacrosse players also (11).

9.3 TRAUMATIC ORAL INJURIES INVOLVING CHILDREN

Recent studies involving children, conducted in a number of countries, generally confirm the rationale and recommendations presented in the 1979 report (14-22). In general, children are susceptible to traumatic oral injury, with those at particular risk being in the age groups one to three years and six to ten years. Although gender-related differences are less apparent in injuries to primary teeth, boys experience a higher proportion of injuries to permanent teeth.

The most frequently injured tooth is the permanent maxillary central incisor (15,19,21,22), sustaining approximately 80 per cent of reported injuries (15,19). Only one tooth was injured in at least 50 per cent of cases reported (15-17, 19-21), with an uncomplicated fracture of the crown being the most common type of injury (15,21,22). Protrusion of incisor teeth and extent of overjet are related to frequency and severity of dental injury (14,22). Prevalence of soft tissue damage appears to be associated with injury to the primary dentition, occurring in at least 50 per cent of cases examined (17,20,22). Relatively few fractures of permanent teeth involved damage to soft tissues in addition to the injury to the permanent dentition (19).

The most frequently cited cause of oral injury is falls, especially among infants and primary school children (22). Next most common are sports- and bicycle-related accidents (18-21), with rugby, soccer, ice hockey and lacrosse accounting for most of the oral injuries sustained through contact sports (18,19).

Risks are also associated with playground environments. The Canadian Standards Association is developing a new standard to apply to play spaces and play equipment provided by parks, schools and community centres (23). Consultation with dental health professionals with expertise in this area seems appropriate to ensure the standard reflects dental health concerns.

Protective Measures

It is impossible to eliminate all traumatic oral injuries in an active child population. However, certain measures can be undertaken to reduce the likelihood of serious injury to the oral tissues: use of well-fitting helmets and face guards and, where indicated, mouthguards during high-risk athletic activities; use of seatbelts and for younger children approved carseats or restraints; and consideration of early orthodontic treatment for children with marked protrusion of maxillary teeth.

In the event of an injury to the mouth or teeth, prompt and appropriate action can minimize damage and reduce the need for extensive future repair. Recommended emergency treatment procedures are outlined in Table 9.2.

9.4 INCREASING THE USE OF PROTECTIVE MEASURES

Research and Promotion

The need for studies and for the dissemination of information on the prevention of oral injuries has been noted previously. Dental health professionals have an important role to play. Their activities, both as individuals and through their professional associations, are to be encouraged. The cooperation of hockey and other sports-league associations, not only in promotion but also in the collection of information on injuries and use of protective devices is also to be encouraged.

Organized Sports

It would appear that measures for the prevention of oral injuries in organized contact sports, while not universal, are gaining in acceptance. Regulations that prohibit dangerous play such as high-sticking and grabbing of face guards and that mandate the use of face and mouth protectors and helmets are in existence. Preventive measures should continue to be promoted by dental health professionals and by all individuals associated with sports. The number of persons who participate in organized sports and potentially could benefit from a preventive program suggests that sport organizations should be a major focus for educational efforts.

Other Risk Groups

Greater attention should be given to those groups that are not a part of organized sports. The special needs of participants in recreational sports should be considered, with a particular emphasis on children. Knowledge of the causes of injury and the availability of effective protective equipment and other preventive measures will not in itself reduce injuries. Parents, teachers, children, players, coaches and instructors must understand and appreciate the value of adopting preventive behaviours. Injuries to the teeth, mouth and associated facial structures can be painful, non-reversible, costly and disfiguring.

TABLE 9.2

EMERGENCY TREATMENT PROCEDURES IN THE EVENT OF TRAUMATIC ORAL INJURY*

	Type of Injury	Recommended Procedure
1.	Bruised or bleeding mouth (e.g., cut lips, tongue or cheek). No apparent injury to teeth.	Apply pressure to stop bleeding. Apply ice on face to reduce swelling.
2.	Loosened tooth	Do not touch tooth. Go to a dentist or to the emergency department of the nearest major hospital which is likely to have a dentist on emergency service.
3.	Chipped or broken tooth	Observe injured tooth immediately. If pink or red inside portion is visible, go to a dentist or emergency department of a hospital as soon as possible to minimize damage to the nerve. If no pink or red is visible inside tooth, arrange for an appointment with a dentist to have tooth checked.
4.	Lost tooth	If a primary (baby) tooth is involved, check it when convenient. If a permanent tooth is involved, it is possible to reimplant it. Wrap tooth in a wet piece of gauze and take as quickly as possible to a dentist or the emergency department of hospital. If the missing tooth, whether primary or permanent, cannot be found, have a chest x-ray to insure that the tooth has not been aspirated into a lung. No matter how minor the accident may have seemed, always have a dental check-up and the injury recorded. Damage (e.g. tooth darkening or nerve death) may not be apparent for some years. Future dental work might be required. In many provinces, accident insurance is available to school children and covers accidents to the teeth. Report any injury to the mouth at the time of the accident for insurance purposes.

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* Adapted from Canadian Dental Association "Protect That Mouth" Pamphlet. Ottawa, 1980.

Regulating for Increased Compliance

If public education programs do not improve the degree of compliance with accepted preventive practices, it may be necessary to regulate the use of specific measures at the organizational level (e.g. sport leagues and school boards). Reductions in the prevalence and incidence of oral injuries have been demonstrated following the introduction of the mandatory use of protective measures by amateur sport associations.

Professional sport organizations have been slower to initiate protective regulations, perhaps due in part to the machismo image cultivated by some sports figures. This situation may change with the transition of younger athletes from amateur to professional status -- athletes who previously played in leagues which regulated the mandatory use of facial protection. Revision of official regulations could be achieved in phases. The National Hockey League serves as an example. It requires all players who have entered the league since the 1979-80 season to wear helmets. Compliance is expected to increase gradually, especially if use is promoted and mandated as necessary for younger age groups.

Modelling Preventive Behaviour

Professional sports figures with their media exposure can influence impressionable young persons. The benefits that could accrue through role-modelling, if noted sports figures endorsed the use of protective measures, could be a major factor in reducing unnecessary injury. Parents, teachers and coaches should also remember the influence that their actions can have when participating themselves in sports.

9.5 CONCLUSIONS AND RECOMMENDATIONS

The evidence reviewed indicates that the findings presented in the 1979 report remain valid and therefore they are reflected in the following recommendations:

1. Mandatory use of CSA-approved face guards and helmets should be considered for players in amateur and professional leagues in hockey, football, lacrosse, rugby and baseball (catcher position).

2. The use of internal mouthguards is encouraged for players in football, soccer, rugger, rugby, field hockey, cricket, basketball, handball, boxing and other sports with a high risk of injury to the mouth and teeth, unless contraindicated by age or particular oral conditions.

3. Use of properly fitted CSA-approved face guards and helmets by children engaged in non-organized, supervised and unsupervised contact sport activities should be promoted. Consideration should be given to making their use mandatory for participation in school programs involving high-risk contact sports.

4. Further research is required to identify risk groups and to develop cost-effective oral protection measures and promotion programs.

5. Dental health professionals at the individual and organizational levels are encouraged to undertake promotional activities concerning the need for and preferred methods of protection to prevent traumatic oral injuries, including involvement, where appropriate, in mouthguard clinics.

6. With regard to the Canadian Accidental Injury Reporting and Evaluation (CAIRE) project, consideration should be given to specifying the site of injury as part of the data collected. This information would facilitate research and development activities for prevention of oral injuries.

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CHAPTER 10

CHAPTER 10

SPACE MAINTENANCE

F. Popovich and G.W. Thompson

10.1 DEFINITION

The loss of primary and permanent teeth as a result of dental caries, accidents or ectopic eruption often is followed by undesirable tooth movements. Space maintainers are appliances that are placed to prevent these undesirable tooth movements. This paper describes the use of space maintainers following the premature loss of primary molars as a result of dental caries, the most common indication for such placement.

10.2 EXTENT OF THE PROBLEM

Dentists who treat children are aware that premature loss of primary teeth is common. Dental surveys (1-4) illustrate that primary molars are extracted prematurely in a significant proportion of children. Some of these surveys show that less than one per cent of children who have suffered early loss of primary molars receive space maintainers.

National and international trends demonstrate significant decreases in caries rates. Recently the Province of Ontario Dental Health Indices Study (5) showed that, at age five primary tooth mortality had fallen from 14 per cent in 1972 to 4.1 per cent in 1984; at the age of seven years the decline was from 32 per cent in 1972 to 10.5 per cent in 1984. Caries immunity (def=0) at five years had increased from 42 per cent in 1972 to 60.4 per cent in 1984; at seven years of age, it had increased from 24 per cent in 1972 to 42.5 per cent in 1984. The 1985 Alberta Survey (6) showed a caries reduction of 35 per cent in 13 years-olds between 1978 (2) and 1985. If the caries reduction trends continue, a much smaller percentage of children will need space maintaining procedures.

10.3 LITERATURE REVIEW

The literature reveals a variety of opinions and evidence concerning the indications for space maintenance. Generally, European orthodontists make much less use of space maintainers, while North American orthodontists and pedodontists seem to use them in nearly all instances of premature loss of primary molars. These two extremes (7) consist of the view that a space maintainer is only contraindicated when a patient expires and those who believe that the use of space maintainers may be a definite benefit, may provide little benefit in many instances or be harmful in others (12).

Jarvis (8) found that tooth loss and interproximal caries were associated with space loss; Lundström (9) and Ronnerman (10) have shown that the earlier extractions (at seven to eight years) contribute more significantly to the development of potential crowding. Lundström (9) has shown that early extractions give rise to increased crowding in the upper arch in 22 per cent of cases, and in the lower in 13 per cent; however, some of these children eventually attained normal spacing. Popovich and Thompson (11) found that primary teeth often were missing in children with crowded and complex malocclusions when compared to those with ideal occlusion and spaced dental arches; the incidence of missing deciduous teeth remained constant (15 per cent) in normals, Class I and Class II malocclusion cases.

Seipel (12), reported space maintainers to have had prevented crowding in 18 per cent of children, had a questionable effect in 51 per cent, produced no apparent change in 15 per cent and an undesirable effect in 15 per cent of his cases. Among 588 13- and 14-year-olds, Hoffding and Kisling (13) found that teeth were lost prematurely three times more often from the mandibular arch than the maxillary arch; in eight per cent such loss was the direct cause of the malocclusion. Dearing (14) examined 354 consecutive children and initiated fixed appliance therapy on 136. Twelve (8.8 per cent) of these malocclusions were due solely to space loss. The findings of Hoffding and Kisling (13) and Dearing (14) were similar to those of Willett (15); that is, 8.4 per cent of malocclusions were a direct result of the premature loss of primary molars, while 52.2 per cent of tooth loss contributed to the malocclusion. In an analysis of dental casts and lateral cephalograms of 104 children, Ronnerman and Thilander (16) found that early loss of primary molars had no general influence on space conditions because crowding is fairly common among children without extraction and children may have a normal occlusal development in spite of extractions. Therefore, children lack space because they have shorter and narrower jaws and have greater mesiodistal tooth width.

Tulley and Campbell (17) generally discourage the use of space maintainers except in dentitions which are not perfect but acceptable. They also recommend their use in the lower arch in Class II Division II malocclusion to prevent the deepening of an already deep overbite and in the upper arch of Class III malocclusions to prevent a lingual collapse of the upper incisors from an end-to-end relationship to an anterior crossbite. Houston and Isaacson (18) believe that space maintainers should be used only when they will avoid the need for or simplify orthodontic treatment; their use should be confined to children who have regular uncrowded arches, good dental health and the premature loss of one or perhaps two primary molars. Stratford (19) also suggests additional prerequisites for successful space-maintainer use such as well-cared-for mouths, regular dental care, intact arches, space conditions either just right or very crowded; also one should avoid neglected mouths and children who are going to have orthodontic treatment. In a detailed longitudinal (6-12 years) study using dental casts of 107 children, Northway et al. (20) found the mean space loss to be 0.9mm. in severe caries, and 3.7mm. with the extraction of lower second primary molars with similar degree of space loss in the upper dental arch when an upper second primary molar is lost. The greatest space loss in both arches was due to mesial movement of the molars and a minor effect from cuspids moving distally. The rate of space loss was age-related because more space was lost during the first year following the extraction. Because of the preponderance of extractions of mandibular primary teeth (the first or first and second primary molars), findings indicate shifting of the lower first permanent molars towards mesio-occlusion, while extraction of maxillary primary first or first and/or second primary molars shifted towards disto-occlusion.

Factors possibly associated with space loss in the dental arches are listed in the following table.

TABLE 10.1

FACTORS WHICH MAY BE ASSOCIATED WITH SPACE LOSS

Dental caries level and susceptibility
Tooth specificity
Chronological age
Dental age
Crowding potential -- mixed dentition analysis
Malocclusion type
Eruption sequence
Oral musculature
Habits
Post-extraction interval
Alveolar bone
Trauma
Anomalies

10.4 TYPES OF SPACE MAINTAINERS

a) Tooth

The original tooth is the ideal space maintainer (21). Therefore, to preserve tooth structure one should promote all phases of caries prevention, restorations, pulpotomies and non-vital tooth therapy.

b) Fixed

i) Crown and loop -- band and loop

These appliances maintain space effectively, however, they may be accompanied by distortion, loss and decalcification of abutment teeth. If roots of successional teeth have not developed far enough, the reinsertion of a different type of appliance may be needed when a first primary molar abutment tooth exfoliates. The design of the loop portion of the appliance is critical. The loop should be sturdy, in close relationship to the tissue, and wide enough to not interfere with the eruption of successional teeth.

In some prefabricated space maintainers, the wire is too light and is elevated several millimeters from the tissue, thus it is deformed under stress and becomes a highly effective lever arm. As a result, the appliance, which was designed to prevent tooth tipping, actively tips the first permanent molar mesially. If the wire loop is too narrow, it interferes with the eruption of the premolar and acts as a catchnet for food.

ii) Lingual archwire: Fixed or removable

Many clinicians regard this as the appliance of choice in a mixed dentition. It maintains the arch perimeter, but when improperly constructed or when the child is not supervised is subject to distortion, crown decalcification and undesired movement of the abutment teeth.

iii) Transpalatal arch

This appliance is recommended when the child has lost one or both upper second primary molars.

iv) Intra-alveolar

These appliances are used to prevent mesial migration of an unerupted first permanent molar following the loss of a second primary molar. On eruption of the first permanent molar, the appliance is modified by cutting off the intra-alveolar portion of the gingival arm or is replaced by another type of space maintainer.

c) Removable

These appliances which maintain arch perimeter and permit normal growth, are used in children with multiple tooth loss early or late in the mixed dentition.

10.5 EFFECTIVENESS OF SPACE MAINTAINERS

Unfortunately few longitudinal studies have been done on the effectiveness of space maintainers. In 72 children, Seipel (12) found that 18 per cent had benefits, 15 per cent had a negative result and the remainder experienced a questionable result. Hill, Sorenson and Mink (22) supervised a study in which fourth year dental students treated 196 children and placed 226 space maintainers. Twelve of these children were lost to follow-up and the remainder were observed for four years, 95 displaying problems. Of these 95, four removable appliances were lost within six months and the remaining 91 children with fixed appliances had an increasing number of problems (breakages of arch or loop, loose bands, removed at home or by private dentist) as the study progressed to the third and fourth year. In the Burlington study (23) treatment records of children showed that those with removable space maintainers required six times more chairtime than those with fixed ones. Hill et al.(22) concluded that space-maintaining procedures should be well planned and the appliances well constructed, and that success required excellent patient cooperation, with long follow-up being necessary.

10.6 GUIDELINES AND PRINCIPLES FOR SPACE MAINTENANCE

Before undertaking preventive space maintenance, the clinician should follow this schedule:

1. Before nine years of age, record complete intra- and extra-oral examination which includes anomalies, trauma and:

a) Molar relationship -- If the molar relationship is end-to-end and therefore more susceptible to mesial migration of the molars, or whether the arches are locking in a good intercuspation and resistant to shift; the former requires space maintenance and the latter does not, if mixed dentition analysis is favourable in both.

b) Occlusion classification -- Loss of a lower deciduous cuspid or molar in Class II, Division II malocclusion would deepen further the already deep overbite because of the lingual collapse of the lower anteriors. In children with Class III skeletal malocclusion, the loss of the same teeth in the upper arch might allow the anterior segment to slide into an anterior crossbite. Both of these situations require a space maintainer, particularly before nine years of age.

c) Time of tooth loss -- The earlier a tooth is lost (especially before eight years), the more likely a space maintainer will be required. If one examines a youngster as a new patient and a tooth has been missing for more than six months without discernible movement, further space loss is unlikely. Concerning this, two situations require special attention.

   i) When a primary second molar is extracted at seven or eight years of age and the lower second permanent molar erupts in advance of the lower second bicuspid, the child can lose space up to a dental age of 11 years.

   ii) When an over-erupted upper second primary molar has stabilized the lower first molar, exfoliation of this upper second primary molar at 11 years of age will release the lower first molar to move forward into the space of the second deciduous molar -- especially under conditions of crowding.

2. Assess the dental development or maturation and eruption status and pattern. Chronological age is not always the best indicator of maturity or status of tooth eruption.

3. Take dental radiographs to determine presence and locations of permanent teeth and amount of alveolar bone covering the permanent teeth.

4. Measure space available to calculate mixed dentition analysis (24-26). A rule of thumb for determining the amount of space required is to:

   a) measure the mesiodistal width of the four lower permanent incisors;

   b) divide sum by two;

   c) in the mandible add 10mm which equals the total predicted width of the lower cuspid and two bicuspids in one quadrant;

   d) in the maxilla add 11mm which equals the total predicted width of the upper cuspid and two bicuspids in one quadrant.

   Space should be allowed for anterior crowding and for the late mesial shift of the lower first permanent molars (26).

5. Make an assessment of the oral musculature and habits in order to determine what forces will be acting on the dentition. Tight facial musculature may encourage tipping back of the upper and/or lower incisors into spaces created by premature loss of primary teeth; thumb and finger sucking may also tip the lower incisors lingually.

6. Determine oral hygiene and general level of cooperation of child and decide whether

future orthodontic treatment may be indicated.

10.7 MIXED DENTITION ANALYSIS

A regression analysis, which uses mainly the individual's mesiodistal width of the lower permanent incisors is the best method for predicting the true mesiodistal width of unerupted cuspid and biscuspid teeth. We prefer this method to measurements of mesiodistal tooth widths on the radiograph.

The most widely used methods have been those of Hixon and Oldfather (24), Staley et al.(25) and Moyers (26) and the clinical rule of thumb noted in the previous section. Most clinicians are familiar with this "10 and 11 rule".

For a detailed space analysis formula, one should refer to the multiple regression equation of Hixon and Oldfather method (24), Staley et al.(25) and Stahle (27).

10.8 SUMMARY

When the first primary molars are lost before the eruption of the first permanent molar, the clinician should install or consider a space maintainer. Also a maintainer should be placed when the same tooth is lost after six years of age in the presence of potentially mild and medium crowding. The loss of the first primary molar, after the eruption of the first permanent molar and lateral incisor generally does not require the placement of a space maintainer in good interdigitating Class I cases without crowding. When the second primary molar or first and second primary molars are lost in children with a "close fit" (no crowding or spacing), a space maintainer should be considered. Children with generalized spacing in the mixed dentitions and good skeletal, occlusal (Class I) and functional balance probably will not need space maintainers, particularly after the dental age of nine years.

For children in the mixed dentition with severe crowding -- (unfavourable mixed dentition analysis), we would recommend serial extraction and orthodontic treatment.

The Burlington data (23) indicate that 20 per cent of 12 year-old children are in serious need of orthodontic treatment; an additional 40-50 per cent could benefit from some degree of orthodontic treatment: these data suggest that 60-70 per cent of children will require more than space maintenance to achieve satisfactory occlusion. In view of these findings, if the child loses primary teeth prematurely, the clinician should consider not only whether a space maintainer is needed but also whether orthodontic treatment is required. It is possible that the same degree of space maintenance might be achieved in conjunction with orthodontic corrective procedures. In any event, the clinician should make a differential and tentative diagnosis in each individual whether he/she plans to eliminate, maintain, regain or create space or to undertake orthodontic therapy.

In premature loss of primary teeth, the degree of subsequent space loss depends upon the tooth lost, the age at loss, whether the tooth was maxillary or mandibular, the degree of spacing and crowding (favourable or unfavourable mixed dentition analysis), occlusion, intercuspation or interdigitation and eruption sequence.

Those who require more detailed and illustrated procedures are referred to articles by Wright and Kennedy (28), Beierl and Hune (29) and Moyers (26).

10.9 RECOMMENDATION FOR NEEDED RESEARCH

A longitudinal study of several hundred children is required in order to determine the long-term benefits for specific types of cases at different ages and different economic conditions so that costs and benefits can be more fully appreciated.

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CHAPTER 11

CHAPTER 11

RECALL EXAMINATION PROCEDURES

J.L. Leake

11.1 INTRODUCTION

Examinations are the systematic inspection of patients' oral conditions to detect present or incipient disease and conditions which may be risk factors for future disease. Dental association fee guides in Canada typically identify at least four different kinds of examinations: complete, emergency, specific and recall. For specialists' services, examination procedures and records are more detailed and at least one specialty group has issued specific procedural guidelines (1).

For a patient who presents with an emergency or a specific complaint, dentists must complete the necessary procedures and tests to ensure a diagnosis and treatment consistent with the patient's needs and wishes. However, dental diseases are commonly felt to be universal in attack and slowly progressive over time. Thus, the regular recall dental examination of asymptomatic people is advocated to detect dental disease at an early stage and thereby enable prompt treatment through follow-up care.

Dentists often use the occasion of the recall examination to perform primary preventive services (or vice versa) although the optimal frequency and timing of the examination and preventive services may be independent.

11.2 PURPOSE

Given that the need for complete, specific and emergency examinations are not in question, this chapter will discuss the need for regular (recall) dental examinations.

11.3 PREVIOUS REVIEW

In the 1979 Report of the Working Group on Preventive Dental Services (2), oral examination procedures were described under three types: i) initial examinations; ii) recall examinations; and iii) screening. The actual components of the first two types were found to be variable and dentists were found to disagree on what services should be considered routine or essential.

The question of the ideal interval between recall examinations (frequency) was also raised and the incongruence of dentists' recommendations, patient practices and the epidemiological evidence of very slowly progressive caries was pointed out. Screening in dental public health was recognized as being controversial and the benefit of using scarce resources to find what was then perceived as ubiquitous diseases such as caries and periodontal diseases was questioned. On the other hand, screening for very rare occurrences, such as oral cancer, was felt to provide too little yield for the cost.

11.4 CONDITIONS NECESSARY FOR WORTHWHILE EARLY DISEASE DETECTION

For many diseases "... the assumption, that active searching for disease in its presymptomatic stage is worthwhile, has been repudiated" (3). For a policy of early (presymptomatic) detection of disease to be of value, five conditions should ideally be met. As described by Hill, Spitzer and Ferenczi, these are:

1. There must be evidence that there exists an efficacious treatment.

2. The test used to diagnose asymptomatic people must be safe, acceptable and have high predictive values (4).

3. There should be evidence from controlled trials that early diagnosis (and prompt treatment) results in an improved prognosis when compared to diagnosis at a later or symptomatic stage.

4. The benefits of early detection ought to be greater than the costs of the early detection.

5. The benefit/cost ratio must be greater than the benefit/cost ratio of alternate uses of the money.

This model for decision making will be used as the framework to examine the rationale for recall examinations for dental caries and periodontal disease. Consideration of the other dental diseases is excluded since there is so little evidence of benefit of early detection. A brief explanation and rationale of the terms used in the model follows to allow readers to approach the chapter in a consistent manner.

Efficacy

Efficacy is the extent to which the treatment results in more good than harm to properly diagnosed patients who fully comply with the regimen. Evidence of efficacy is strongest if demonstrated by a randomized controlled trial (RCT). Many commonly accepted dental procedures have not been evaluated in a RCT. Where this has occurred some have been found to be of no value (5,6,7,8), or of no additional benefit to a less radical procedure (9). Even with an efficacious procedure, the dental health of Canadians can not improve if there is no accurate diagnostic test; if providers don't look for or treat the disease (10); if patients' compliance is low (11,12); or, if the target population is not reached (13).

Diagnostic Test

While the safety and acceptability of a diagnostic test need no explanation, "high predictability" refers to the accuracy of the test as measured against "truth" or a known "gold standard". Figure 11.1 illustrates how people receiving such a diagnostic test actually fall into four categories (true or false positives or true or false negatives) (14,15).

The dental literature shows an increasing use of these criteria to evaluate the suitability of commonly used diagnostic tests of disease activity and to evaluate those tests which are being developed (16,17,18,19). While sensitivity and specificity are important characteristics of a diagnostic test, the clinician is often in the position of not having a "gold standard" to go by; otherwise, why perform the test? Thus, interest is more often in the predictive values of the diagnostic test in question.

Evidence of Improved Prognosis

Dental disease is often thought to be neither self-limiting nor self-repairing and, if this is so, the practice of regular and frequent recalls is justified. However, with the changing dental caries susceptibility, it can be argued that intervention at too early a stage in dental caries denies the natural and acquired defence mechanisms the opportunity to reverse or arrest the early decay process (20,21). Similarly, if periodontal disease is characterized by random bursts of activity with long periods of quiescence (22), the question of "early" diagnosis becomes more a question of "timely and accurate" diagnosis of these periods of activity.

The early diagnosis and treatment of many malocclusions is also thought to improve prognosis. However, the benefits of care are not demonstrated by controlled studies and are not easily detected in prospective or cross-sectional studies (23,24,25). One reason may be that the stability of the correction is not always assured (26). While the correction

FIGURE 11.1

ASSESSING A DIAGNOSTIC TEST

"Truth" or "Gold" Standard

		Disease	
		Present	Absent
Diagnostic Test	Positive (Disease probably present)	a (true positives)	b (false positives)
	Negative (Disease probably absent)	c (false negatives)	d (true negatives)

Positive predictive value = proportion of diseased persons (true positives) so identified by the test:
$= a / (a + b)$

Negative predictive value = proportion of non-diseased persons (true negatives) so identified by the test
$= d / (c + d)$

Accuracy = proportion of diseased and non-diseased persons (true positives and negatives) so identified by the test
$= (a + d) / (a + b + c + d)$

Sensitivity = proportion of diseased persons in the population so identified by the test:
$= a / (a + c)$

Specificity = proportion of non-diseased persons in the population so identified by the test:
$= d / (b + d)$

Source: Last (14) and Lilienfeld and Lilienfeld (15) of many oro-facial deformities is believed to be more efficient if timed to coincide with periods of facial growth (27), many deformities are corrected in adult patients. Thus, early diagnosis may contribute to a shorter treatment phase and, to the extent the final results is stable, the avoidance of psychosocial trauma during the teenage years (28).

Benefits and Costs

The costs of six-month visits are undoubtedly high. By way of illustration, the cost of 50 per cent of Ontario's population visiting a dentist for one recall examination, using the 1985 Ontario Dental Association Fee Guide, would exceed $66 million.

Health benefits are often difficult to quantify in dollar terms and health economists are increasingly using the abstract notion of marginal utility. This is the ratio of preference (sometimes determined by "willingness to pay") for early treatment results divided by the preference for late treatment results. Thus, if the disease is not very prevalent, the utility ratio has to be much higher since only the few persons detected with disease have the benefit of early treatment while the costs are borne by all who visit and/or pay for recall examinations. Similarly, if the differences in preferences are not large, (i.e. the difference in preferences between a small restoration versus a somewhat larger restoration with a lining to insulate the dentin) the costs of early detection would have to be very small to justify identifying all diseases at the earliest stage.

Comparing Benefit/Cost Ratios

In current jargon, this is the "biggest bang for the buck" question. If, on a total society level, we compare the benefits of frequent recall examinations, we must decide if they would be greater than those of spreading dental care to currently underserviced groups such as the elderly, cleft-palate children, etc., or extending a more comprehensive service to welfare clients. On an individual level, the question is whether there is more utility (enjoyment, satisfaction, health or whatever) to visiting a dentist for a recall visit compared to the utility of an alternate use of the same money and time.

11.5 PERIODONTAL DISEASE: NATURAL HISTORY AND PREVALENCE

The most common form of periodontal disease has been classically described as slowly progressive with age, from health to gingivitis, to periodontitis, to loss of teeth (29,30,31). In the mid 1960s, Loe and others established that gingivitis or localized inflammation could be induced by stopping all oral hygiene procedures and reversed by the implementation of such procedures (32). Classical periodontitis (now called adult periodontitis), where attachment and bone loss result in the eventual loosening of the teeth, is now recognized as only one of a family of, perhaps, five diseases. It seems certain that organisms from the normal flora opportunistically infect and induce pathology in the structures supporting the teeth. The various forms of periodontal disease are the result of the complex and, as yet, not well understood, interaction of the particular organisms, local tissue responses and the host's immune system (33).

The valid measure of adult periodontal disease is the progressive loss of attachment with bone loss (17). From cross-sectional survey data, there appears to be an annual average loss of attachment of 0.05 to 0.1mm per year (34,35). However, in any one year most sites are not actively diseased and don't change beyond a threshold amount -- which is believed to be outside of the measurement error (36) -- namely, 2mm (37). As examples, in one Swedish group, 30 to 64 people had no change in any site over six years and five people had over 50 per cent of the sites that did change (37). In untreated Irish textile workers, 39 per cent of teeth had the same periodontal index score at baseline and ten years later. Of the remainder, 10 per cent improved and 51 per cent worsened or were missing (38). In a United States trial over three years, the lack of destructive disease in the 69 adults studied precluded any conclusions on the relative merits of the two regimens being compared (39).

In a review of United States' national survey data, Douglass et al.(40) showed that the proportion of adults with no disease nearly doubled between 1960/62 and 1971/74. Coincident with this, they found a large decrease in the prevalence of gingivitis and a small decrease in those with pockets in the 18-34 year-olds. Among the elderly, data from a representative sample from the United States show that periodontal indices were similar to those in younger dentate adults and that some calculus and debris appeared to be consistent with acceptably low levels of periodontal disease (41).

Thus, periodontal disease may not be the scourge of the total population but rather a disease of relative stasis with apparent random, rapid bursts of activity in some teeth in some individuals (19,22). Further, there is evidence that Canadian groups are as healthy as, if not more healthy than, United States groups (42).

As evidence, Ontario's 13- to 14-year-old children had the lowest periodontal scores among seven countries studied in the International Collaborative Study (ICS) (42). Main (43) found pocketing among 9 per cent of eight-year-old children living in North York, Ontario. Ninety-two per cent of adolescents in Saskatchewan exhibited bleeding upon gently probing on one or more teeth (44), but only 15 per cent had pockets greater than 3mm (45). In the Canadian Forces recruits (median age 19 years), 21 per cent had signs of gingivitis only. Thus, only 13 per cent had had periodontitis and none had had advanced forms defined as probing depths of 6mm or more (46).

In international comparisons, the periodontal health of Ontario adults was the best of all those in the other six ICS countries (42). No other recent representative Canadian data exist for an adult population. In the clinical population of the Faculté de médecine dentaire at the Université de Montréal, 78 per cent had periodontal disease and 18 per cent had chronic periodontitis (47). Among serving members of the Canadian Forces, 17 per cent were free of disease, 54 per cent had gingivitis only and 30 per cent had had moderate or advanced disease (46).

The Hill et al.(3) model described earlier will now be applied to help decide whether it is worthwhile to detect periodontal disease early.

1. Is There an Efficacious Treatment?

Treatment Phase

In the past, the operating definition of a periodontally diseased site has been a site which has a probing depth beyond an arbitrary level, often 3mm. Clinical trials have been conducted to compare the efficacy of one therapy to another in reducing or at least maintaining such probing depths or, conversely, increasing or maintaining the level of attachment.

Within the limits of the design of the studies, pockets of medium depth (4-6mm) have been shown to benefit from both non-surgical interventions (scaling and root planing) and surgical procedures. Deep (6+mm) pockets benefited more from light surgical care (modified Widman flap where the purpose of the surgery was to improve access for scaling and root planing) than from deep scaling. For shallow pockets (1-3mm), both types of care resulted in loss of attachment although the unwanted result was more pronounced with surgical care (35,48,49,50,51). The best results for surgery were obtained on deeper sites which were maintained free of subgingival plaque during a full healing phase of six months (50,52) which was achieved with frequent (two-week) recall visits.

Loesche has proposed that periodontal diseases are the result of specific bacterial infections, leading him to propose specific antibiotic therapies (53), in particular, metronidazole, as a supplement to traditional mechanical debridement procedures (54).

In one preliminary report (35) of a longitudinal study of tetracycline and modified Widman flap therapy, the disease was defined differently, as actively breaking down sites instead of pockets of a specific depth. Active sites were operationally defined as ones in which there was recent loss of attachment beyond a reliably detectable amount of 2-4mm. Two findings were significant. First, fewer than 5 per cent of sites were found to be actively breaking down or truly diseased. Second, "active" sites in juvenile periodontitis patients responded significantly better to therapy than "active" sites in adult periodontitis individuals and better than inactive sites in both groups (35).

Thus, while there are consistent findings on the efficacy of treatment which leads to an improvement in attachment levels of deep pocket (based on studies in Minnesota, Michigan, Arizona, Sweden and Massachusetts), a new approach to defining the disease in one preliminary study (35) has raised questions as to whether the major benefit occurs at all sites or just at those with active disease. These same authors have also pointed to the need to consider the subsequent maintenance phase as the major contributor to the efficacy of any, but particularly, surgical treatment.

Maintenance Phase

It is advocated that following the active treatment phase, a maintenance phase of visits once every three months is necessary to evaluate oral hygiene standards and to scale and polish the teeth. Once a year examinations are also advised (55).

The recent literature on maintenance care falls into three categories: descriptive reports (collected case studies or reports gleaned from clinical trials of other therapies); comparable but separate reports on maintained and non-maintained groups by the same researchers and controlled studies.

The findings from descriptive studies are clouded because comparison groups were lacking, initially most subjects had advanced disease or had been treated surgically and the ages of patients, maintenance regimens and frequency of their application varied (48,49,52, 56-66). However, there is no consistent evidence of the efficacy of any one maintenance regimen applied at a standard interval. For United States groups, maintenance care at three- to four-month intervals may meet the needs of all but 4-8 per cent of people with moderate to advanced disease. There is, however, no evidence as to whether such a short interval is necessary or whether it could be extended to 6, 12 or 18 months without prejudicing the results. However, even frequent and intense levels of care did not prevent all subsequent tooth loss.

In the comparable studies (12,67,68,69) the groups were not randomly assigned between maintenance and non-maintenance care and our conclusions again must be guarded. In Sweden, two-week cleanings may be sufficient to prevent further attachment loss after surgery but whether they are necessary has not been demonstrated. In the United States, three- to four-month maintenance visits were not sufficient over six years to entirely prevent attachment and tooth loss. In spite of the problems in interpreting the data on average losses, the contrast between the two treated but non-maintained groups is dramatic. The Swedish group lost 1mm of attachment in 18 months, whereas the United States group lost 0.13mm over 5.25 years.

Table 11.1 sets out the results of the controlled studies. Again, there is a contrast between studies in the United States and those in Scandinavia. One difference was that, in the United States, the studies were conducted on people who had had no surgical care since they had little initial disease. In both studies by Suomi et al.(70,71), there were no clinically meaningful differences between the groups with different frequencies of maintenance care. Some of the statistical difference (70) shown in the table occurred within the differences expected due to measurement error (36,39). Similarly, Lightner et al.(72) reported that there was no clinical advantage to a third and fourth visit compared to two 30-minute treatments given 5-11 days apart. For United States populations, these subjects showed high rates of average loss of attachment, from 0.15 to 0.32mm per year. In Listgarten's (39) study, no definite destructive disease probing depth

TABLE 11.1

PERIODONTAL MAINTENANCE: CONTROLLED STUDIES

Investigators/ Year	Study		Maintenance Regimen	Sample			Outcome
	Location	Duration		Size	Starting Age	Starting Disease	
Suomi et al. 1971 (70)	California U.S.A. Electronics Firm	3 yrs.	Test: 11 prophys, 2-4 mos. apart and repeated OHI Control: continued usual OH practices	T: 163 C: 163 (Individually matched pairs)	18-40 Mean 31	Minimal attachment loss	Per cent Distribution of Teeth with Changes in Attachment; Extractions Gains ≥ 2 mm; ± 1mm; Losses ≥ 2mm; Extractions T: 1.8; 94.6; 1.2; 2.4 C: 1.1; 93.5; 3.0; 2.4 X2 = 11.8; P < .02 @ 3 d.f.
Lightner et al. 1971 (72)	Texas U.S.A. Air Force Academy	46 mos.	Group yearly treatment schedule 1: 1,50 min. calculus removal 2: 2,30 min. trts 5-11 days apart plus 2,10 min. OHI 3: as above plus 1-30 min. trt. plus 1,10 min. OHI in 6 months 4A: 4,30 min. trts and 4 OHI 4B: 4,30 min. trts	470	- (younger than 31)	not stated	Loss of Attachment Grp; (n); Number of Affected: Men; Teeth; Mean (mm) Loss Per: Man; Tooth 1; 108; 40; 82; 1.23; 1.62 2; 121; 46; 81; .94; 1.41 3; 110; 34; 64; .83; 1.42 4A; 64; 18; 26; .58; 1.42 4B; 67; 22; 39; .78; 1.33 "..preventive regimen given to Group 2 ...would be both practical and effective."
Suomi et al. 1973 (71)	Connecticut U.S.A. Coast Guard Academy	3 yrs.	Grp. 1: 1 prophy annually Grp. 2: 2 prophys annually Grp. 3: 3 prophys annually No OHI	1: 140 2: 143 3: 140 (Group matched)	17-22	Good dental health	Attachment Levels (mm.) Grp.; Base; Final; Difference 1; 0.03; 0.10; 0.07 2; 0.03; 0.08; 0.05 3; 0.04; 0.09; 0.05 "no clinically meaningful differences"
Nyman 1975 (74)	Gothenburg Sweden Research Clinic	2 yrs.	Test: staining, professional cleaning, TBI, interdental cleaning instruction every 2 weeks Control: scaling every 6 months	T: 10 C: 10 (Random)		Post-surgery for advanced periodontal disease	Attachment level changes from 6 months to 24 months Test: +0.1mm Control: -2.2mm Significant loss of attachment in controls
Rosling et al. 1976 (75)	Gothenburg Sweden Research Clinic	2 yrs.	Test: staining, professional toothcleaning, TBI, interdental cleaning instruction every 2 weeks Control: prophylaxis every 12 months	T: 12 C: 12 (Random after age matching)	29-68	Post-surgery for advanced periodontal disease	Attachment level change 6 mos.; 12 mos.; 18 mos. T: +3.0; +3.2; +3.5 C: -1.0*; -1.2*; -2.1* *T vs. C different p < 0.001

Notes: TBI is toothbrush instruction
OHI is oral hygiene instruction

TABLE 11.1 (Con't)

PERIODONTAL MAINTENANCE: CONTROLLED STUDIES

Investigators/ Year	Study		Maintenance Regimen	Sample			Outcome
	Location	Duration		Size	Starting Age	Disease	
Axelsson and Lindhe 1981 (76)	Karlstad Sweden Research Clinic	6 yrs.	Test: OHI, and professional prophylaxis each 2 mos. for 2 years and each 3 months for 4 years Control: recalled yearly for symptomatic care in public health clinic	T: 310 C: 146 (Basis of assignment not stated)	20-71	Private and public health clinic patients	Data presented graphically T: no significant attachment changes over 6 years C: loss of 0.13 to 0.26mm in attachment per year
Axelsson and Lindhe 1981 (73)	Gothenburg Sweden Research Clinic	6 yrs.	Test: instruction and practice in OH, meticulous scaling and professional toothcleaning each 2 mos. for first 2 years each 3 mos. for 3-6 years. Control: referred to private dentists with letter stating periodontal recall necessary	T: 52 C: 25 (Every third patient referred)	50	Post-surgery for advanced periodontal disease	Per cent Distribution of Sites Improved / Stable / Worse ≤ 1mm / Worse ≤ 2mm T: 17 / 72 / 10 / 1 C: 1 / 10 / 34 / 55
Listgarten et al. 1985 (39)	Philadelphia U.S.A. Research Clinic	3 yrs.	Test: prophys from 6 to 36 months apart: given only when DDFM scores indicated. Control: prophy each 6 mos.	T: 30 C: 31 (Random)	20-73	Gingivitis only	Increase of probing depth of 3mm or more occurred 21 times in 38,228 measures. Not enough disease to measure difference.

Notes: TBI is toothbrush instruction
OHI is oral hygiene instruction

increases occurred in spite of prior gingivitis among all participants. In that study, 11 of the 30 test patients maintained periodontal health with no prophylaxis over the 36 months of the study.

In the Karlstad study by Axelsson and Lindhe (73), clinic patients in the test group, seen at intervals of two to three months for six years, showed little or no change in attachment. The control group lost from 0.13 to 0.26 mm of attachment each year. However, test and control patients were from different populations, i.e. they were not randomly assigned.

The other three controlled Scandinavian studies (74,75,76) were conducted on patients who had been treated for advanced periodontal disease by surgical means. In these patients there is a benefit to frequent cleanings where the frequency varied from every two weeks to every two to three months, compared to six- or 12-month prophylaxes or care from private dentists. Again, the average loss of attachment in two control groups was extreme, 1.0mm (74) and 1.1mm (75) over the last 18-month maintenance phase of the studies but less severe, 0.3mm (76) per year, in the third.

We are left with the result that for United States' (and presumably Canadian) groups of younger, relatively disease-free individuals, the disease, as measured by progressive attachment and bone loss over a three year period, is unusual and that maintenance visits as frequent as three months are not necessary. Lightner (72) favours two 40-minute sessions 5-11 days apart once each year. Listgarten's (39) data show that some individuals, even with prior gingivitis, could be seen no more than once every three years and still have no active disease. For moderately diseased individuals there are no studies and, for people with advanced disease, there are controlled studies only for Scandinavians who, if the disease is measured in the same manner as in the United States, appear to have much more rapid destruction than United States and presumably Canadian populations.

Keyes Technique

Since the late 1970s there has been controversy over a "new" form of therapy for periodontal disease advocated by Dr. Paul Keyes and associates. The treatment consists of scaling and root planing, subgingival application of salts and peroxide, an antibiotic and home rinses. All of these were adjusted according to information derived from monitoring microbial colonies (77). A "Blue Ribbon Committee" of the American Academy of Periodontology reviewed the material and reported that "... the committee seriously doubts that scientifically valid conclusions (about the superiority of the technique) can be drawn ..." (77). While this report is disputed as to the facts and conclusions (78), the final answer awaits the evaluation of published, randomized trials.

Is there an efficacious treatment for periodontal disease? The conclusions are clouded because the natural history of the disease is poorly understood and the operational definition of the disease in clinical trials is changing and, therefore, the assessment of the efficacy of treatment and maintenance is difficult. Further, the review of maintenance care literature has not been helpful, other than to show a major difference between Scandinavian and United States populations and that there is no definitive estimate of the optimal maintenance period. The optimal maintenance schedule is probably variable, with some adults with mild periodontal disease or gingivitis needing to be seen less frequently than once each year and those with active disease or post-surgical patients benefiting from more frequent (as frequent as every three months?) visits. However, as the collected case reports and the Scandinavian control groups demonstrate, even frequent care or care by dentists outside research situations does not assure health for all patients. Further, the home maintenance preventive regimen is followed by some (79) but not all patients (80) and may be unrealistic in terms of the effort required for the benefit (35).

2. Is There a Safe, Acceptable, Accurate, Diagnostic Test?

"A reliable method to diagnose ongoing (periodontal) disease activity still eludes the profession" (81).

"I would submit that the most profound problem in clinical periodontology today is the lack of precise criteria for disease activity and for identifying patients at risk" (82).

These two quotations outline another current dilemma with periodontal diseases. Commonly used clinical indicators, such as gingivitis and pockets, are not useful in predicting destructive periodontal disease activity. The Forsyth (17) group were the first to illustrate this although Badersten et al.(19) have reported similar positive predictive values on interim or post-treatment measures. In both cases, the clinical signs were compared to the "gold standard" of actual increases in probing depth over two and three months. Using the assessment criteria described in Figure 11.1, some selected comparisons from Haffajee et al.(17) are shown in Table 11.2. These illustrate the accuracy of the clinical parameters compared to subsequent probing-depth changes.

Starting with the right-hand column, the clinical parameters were from 71 per cent to 95 per cent accurate but all of that accuracy was the result of the very high negative predictive values of the tests. High negative predictive values mean that teeth with no clinical signs rarely have increases in probing depth. However, the positive predictive values are extremely low. For example, only 3 per cent of teeth exhibiting initial bleeding subsequently had increased probing depths. "Molar teeth" was a better positive predictor as 4 per cent had subsequent increases in probing depth. "Molar teeth" was the most sensitive (0.52) clinical parameter and (the absence of) suppuration was the most specific clinical parameter. Thus, in this population, with an incidence of active disease of 3 per cent, no one clinical parameter identified even 5 per cent of the future disease (as defined by subsequent, increased probing depths), although a tooth without those clinical parameters did not become diseased about 98 per cent of the time. Some improvement was reported when "molar teeth" and one clinical sign were used but the probability of a false positive result was still 0.85 for molar teeth and bleeding. Increases in probing depth were better identified (0.53) by using three interim or post-trial signs but the sensitivity of the three indicators was still only 0.13 (17).

Thus, we have no clinical parameters which are useful in identifying active or future disease. Similarly, there are no acceptable diagnostic tests using other means, such as radiographs (83), gingival fluid, leucocyte or microbial assays (81,84), although ^{125}I absorptiometry may be useful for research studies (85).

While a large change in probing depth is a valid indicator of active disease (17), problems occur in its reliability since one commonly used reference point, the cemento-enamel junction, may not be detected reliably (86) and variation in probing force results in different probing depths (87). Further, while calibrated and practised examiners in a research setting could reproduce probing depth measurements within ±1mm 90 per cent of the time (88), no evidence exists to show how well general or specialist practitioners can repeat themselves on such measurements.

3. Is There Evidence That Early Diagnosis and Prompt Treatment Improves Prognosis?

"... preventive and therapeutic procedures (for periodontal diseases) are primitive, demanding and some are not cost effective ... (the) elimination or dramatic reduction in the prevalence of periodontal diseases may not occur until fundamentally new approaches to their control have emerged ..." (82).

In the treatment phase of periodontal disease, the largest gains in attachment occur in deep pockets (48) which are presumed to be a later manifestation of the disease process. However, medium pockets still show comparatively higher levels of attachment and bony support after treatment. Assuming that a higher attachment

TABLE 11.2

CLINICAL SIGNS AS PREDICTORS OF INCREASES IN PROBING DEPTH

			Predictive Value		
Clinical Sign	Sensitivity	Specificity	Positive	Negative	Accuracy
Plaque	0.42	0.71	0.03	0.98	0.71
Bleeding	0.25	0.80	0.03	0.98	0.79
Suppuration	0.03	0.97	0.02	0.98	0.95
Pockets	0.10	0.92	0.02	0.98	0.88
Molar teeth	0.52	0.72	0.04	0.99	0.72

Source: Haffajee, Socransky and Goodson (17)

level improves the prognosis of retaining the tooth, then there is benefit to the early diagnosis and treatment of medium (4-6mm) pockets before they become deep. However, there is harm in surgically treating shallow pockets or sulci (1-3mm) since they lose attachment more rapidly after such treatment compared to pockets treated non-surgically (48,57,58). These observations are derived from clinical trials where early diagnosis and prompt treatment were not the variables being tested so they can not be stated with absolute confidence. However, neither Srikandi et al.(89) nor Beck et al.(90) found any effect on periodontal health status of regular visits to the dentist where the benefits of early detection might be found. Sheiham (91) argues that there is no reliable evidence that earlier detection alters the natural history of the disease.

4. Is There Evidence That the Benefits of Early Detection Are Greater Than the Costs?

One study simulated the lifetime direct costs of different kinds of dental care, including those with optimal prevention and frequent recalls (92). The cheapest form of care was found to be total neglect, a finding which holds true for any health care. Lifetime costs of annual examinations and frequent professional toothcleaning were found to have a present value of $1,856 to $4,018 depending on whether preventive care was provided by an auxiliary and whether the person resided in a fluoridated area. However, the benefits of different health states were not compared, a problem that dental research is just beginning to address (93,94,95). Thus, since concrete evidence is lacking about both the efficacy of the various streams of care and the value of the improved health states that might occur, one can only conclude that there is an absence of evidence that benefits of early detection are greater than the costs.

5. Is There Evidence That the Benefit-Cost Ratio of Early Detection and Prompt Treatment is Greater Than Alternate Uses of the Money?

This is a question that cannot be addressed at this point since there is a complete dearth of evidence in the area.

Summary -- Periodontal Disease

In summary, there is some evidence of the efficacy of periodontal therapy (treatment and maintenance) for people with deep and moderate pocketing, especially, and perhaps only, for those with active disease. However, active periodontal disease (loss of attachment and bone) is relatively uncommon and the likelihood of its occurrence cannot be assessed accurately before its occurrence. Further, there appears to be some remission of the disease among untreated groups (37,38). With these problems, it is understandable why the benefits to early detection and prompt treatment are difficult to find, let alone quantify, in order to evaluate the utility of early detection.

In light of the relatively low prevalence of active disease, it is difficult to recommend the continuation of six-month examinations for all dentate people. For Canadian populations who presumably are more like United States groups, recordings of the attachment levels of susceptible sites (molar teeth) could, on the basis of the Lightner, Suomi and Listgarten studies (39,70,71,72), be made less frequently (one to two year intervals?) until changes are detected, then more active therapy and frequent examinations (at three to four month intervals?) instituted until stable attachment levels are achieved.

All of this represents "cut and fit" as opposed to "precise scientific" technology but until better diagnostic tests and the efficacy of therapies are proven, this reviewer and the clinician are left with having to make decisions on a very inadequate knowledge base.

11.6 DENTAL CARIES: NATURAL HISTORY AND PREVALENCE

A dental caries lesion starts at the tooth surface with the demineralization of the enamel which appears clinically as a white spot. Morphologically, this initial lesion has an intact surface but the sub-surface is demineralized (96). At this stage, the incipient lesion may be arrested or even reversed through a process involving the saliva with its concentrations of minerals and fluorides (20,21). The process of arresting or reversing the incipient lesion is enhanced by preventive measures such as using a fluoride dentifrice or fluoride rinse or by having fluorides applied topically. In normal populations an initial lesion that develops into a clinical cavity does so slowly and intermittently. When frank cavitation (obvious destruction of the intact enamel surface with extension into the dentin) occurs, the lost tissue should usually be replaced by a restoration (96) to prevent extension of the process to the pulp and the concomitant pain and ultimate loss.

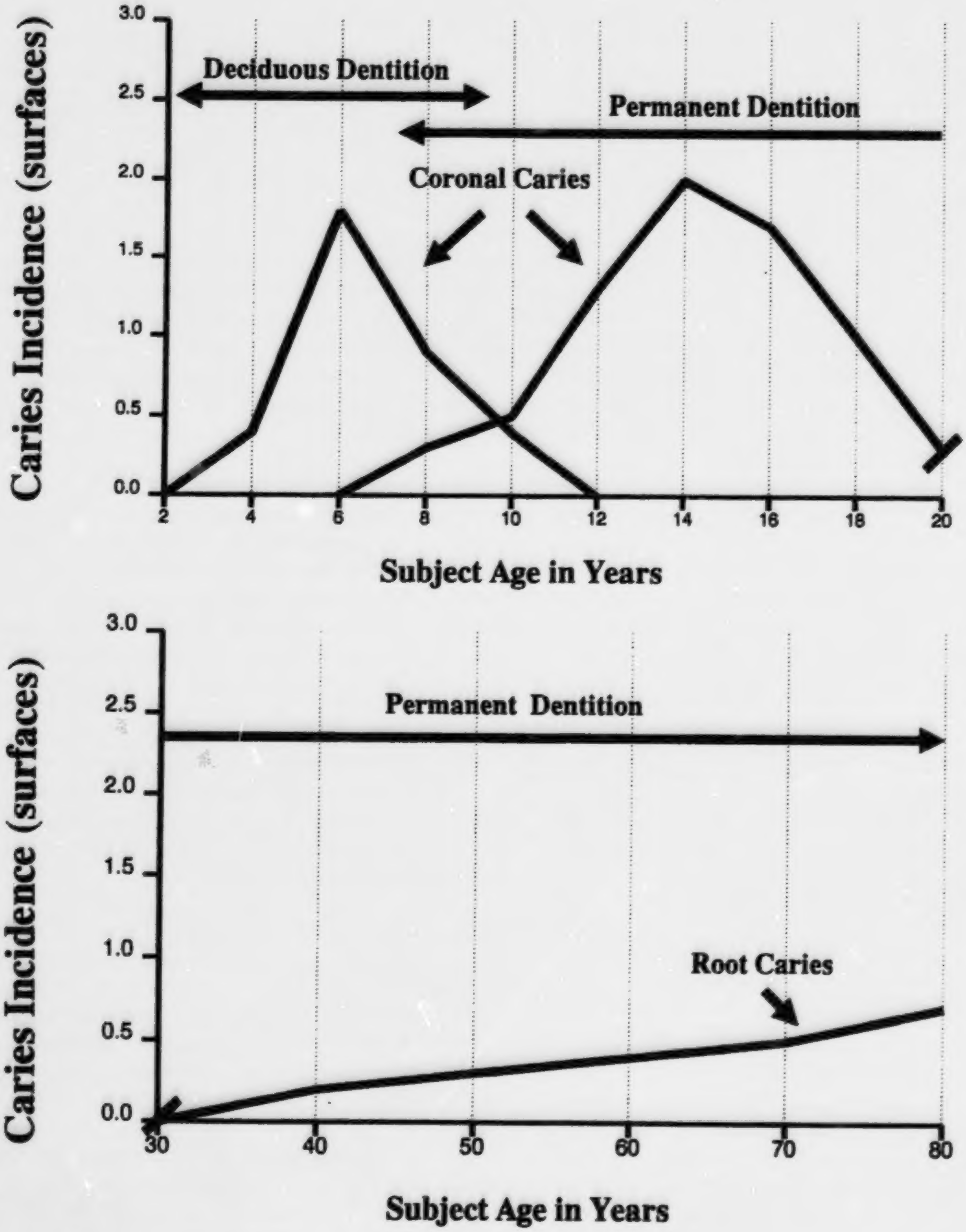
The pattern of dental caries incidence has been described as trimodal with peaks of incidence occurring for enamel caries in early childhood and teens and root caries becoming more evident in adulthood. This has been described graphically by Stamm (97) as shown in Figure 11.2.

While viewed at one time as a universally prevalent disease, coronal dental caries is declining in the United States and Canada (98-104). This fact is also becoming part of the media's message to the public (105). What does this decline mean in terms of current and future patterns of disease? First, the age of onset of any caries is delayed. In East York, a Toronto Borough, in 1964, 84 per cent of children from senior kindergarten to Grade 3 (average age of seven) had experienced decay. In 1984, only 42 per cent of seven-year-olds had had any caries. In one affluent area nearly 83 per cent of senior kindergarten children had had no caries experience (106).

Second, and as a corollary of the first, it should be noted that at any age, the per cent of children who have never had a cavity is much higher. As an example of this, in Ontario in 1972, 8 per cent of 13-year-old children had a DMFT score of zero. This percentage had almost tripled to 23.7 by 1982 (98).

Third, the annual increment of caries surfaces among children in the United States is far less than the 2.0 often assumed (107). In the recent National Preventive Dentistry Demonstration

Figure 11.2
APPROXIMATE PATTERN OF DENTAL CARIES INCIDENCE OVER THE LIFETIME OF AN AVERAGE DENTATE



Source: Stamm (97)

Program (NPDDP) (108), the highest increments of decay occurred in the adolescent group of controls in non-fluoridated areas. That rate of 4.75 surfaces over the four study years is 1.2 surfaces annually. The three other control group DMF surface increments were 0.55, 0.76 and 0.78 annually. This very low rate of increment may not apply to all Canadian groups. Nonetheless, the control group in caries studies in a non-fluoridated, high caries area (Sherbrooke, Quebec) experienced an annual increment of 1.2 DMF surfaces over 20 months (109) corresponding to the highest experience in the NPDDP.

Fourth, many children are likely to have little or no new caries experience in any short or medium period. In the NPDDP, between 21 per cent and 39 per cent of the four control groups of children had no decay over four years. Between 34 per cent and 45 per cent of the control groups acquired an average of one or fewer decayed surfaces annually. From this study, the chances, over four years, of children in the control groups acquiring more than one new cavity per year was between 16-46 per cent (108). Bohannan (110) reported that the worst 20 per cent of children had 50 per cent of the new caries.

Fifth, more than half of the increment in caries comes from fissure caries (108). However, even that was sufficiently low, such that in the NPDDP baseline studies, fissure caries on first permanent molars had not affected half of the teeth until age ten or older (110).

Given this likelihood of low future caries, finding disease from any examination of asymptomatic children (known as yield) is going to be lower than in the past. This prompts some review of the recommendation for parents to bring children to the dentist at three years of age and for each six months thereafter.

Among adults, the evidence is too sparse to make an estimate with any confidence. The recently released study of Canadian Forces Personnel shows that recruits' DMFT scores were 12.3 in 1983 compared to 14.6 in 1967, a reduction of 16 per cent (46). Based on consistent evidence from similar non-representative samples, Graves and Stamm (101) feel that young adults are also experiencing the decline in caries. Older adults, on the other hand, had high caries experience in the past, thus their DMFT scores remain high even though the incidence of coronal caries among this group is presumed to be low.

A site of future caries attack may well be the exposed roots of teeth among older adults which will not have been lost in young adulthood (111). However, as Burt (103) points out, these lesions are likely susceptible to the same influences (fluoridation, topical fluorides in dentifrices and rinses, etc.) that are reducing the burden of coronal caries. The United States study of adults (112) currently underway should assist in estimating the onset and extent of root caries in the United States' population.

Is it Worthwhile to Detect Dental Caries Early?

1. Is there an efficacious treatment?

The restoration of a decayed tooth prevents the extension of that lesion and restores the tooth to function. However, restorations have limits to their longevity and require replacement. In a recent review, Maryniuk (113) found that in longitudinal (uncontrolled) studies, the half-life of amalgam restorations was between 5.5 and 11.5 years. However, using evidence from recent controlled clinical trials, an extrapolated half-life would be between ten and 14 years. Boyd and Richardson (114) found that dentists in British Columbia replaced 6.8 amalgam surfaces per working day with caries around or under the restoration being 50 per cent of the reasons for replacement.

The efficacious treatment for incipient lesions may also be an intervention for primary preventive purposes. There is demonstrated efficacy for various topical fluorides (Chapter 6) and fissure sealants (Chapter 3) and frequent prophylaxis plus fluorides (115,116). Thus, subsequent prevention for a person identified as having an incipient carious lesion is also efficacious.

2. Is there a safe acceptable screening test with high predictive values?

a) Testing for Needed Restorations

Dental caries is detected by clinical (visual-tactile) means using a good light source, a dental mirror and a sharp dental probe or explorer. The clinical appearance of enamel caries on visible smooth surfaces varies from early signs of caries activity but no cavitation (e.g. visible white spot lesions) to early cavitation (e.g. a tactile, catch or break in enamel) to frank lesions, detectable with even a cursory look.

For interproximal surfaces, the latter two signs may also be evident. However, dental radiographs are used to detect the early loss of mineral salts from these surfaces which are difficult to see and probe. Classification systems to describe the radiographic position of lesions within the enamel and dentin have been developed by several investigators and standardized criteria have been proposed by Pitts (117).

However, considerable variation in interpreting clinical and radiographic signs can be found among examiners in clinical trials (118), dental practitioners (119) and university dental teachers (120), and quite different decisions in planning treatment result (121). When the lesion was seen to be two-thirds or more through the enamel, the positive predictive value of radiographic diagnosis was found to be 0.52 by Mejare et al.(122) and 0.61 by Grondahl (123). Even when the lesions were radiographically into the dentin, only 50 per cent showed macroscopic cavitation (124). Lesions were only unambiguously diagnosed when they were shown on the radiograph to have penetrated deep into the dentin. For probing smooth surfaces, positive predictive values were found to be 0.50 to 0.57 or about the same as using the criterion of a radiolucency extending at least two-thirds into enamel (122). These values are prompting several investigators (123,124) to recommend caution in restoring such sites, preferring that the later signs be used before restorations are placed.

In pits and fissures, the detection of caries is difficult and epidemiological survey systems opt to record caries only when a frank lesion with a softened floor or adjacent demineralization is detected (125). For these surfaces, radiographs are not felt to be helpful and the predictive values of probing pits and fissures has not been investigated.

Thus, practitioners' confidence in the diagnostic criteria for dental caries can not be fully justified until the signs of decay are relatively late. However, given that the later signs are used, there are safe, acceptable diagnostic tests for existing caries.

b) Testing for Needed Prevention

One area of continuing interest has been the development of a test which could be used to predict future caries in order to make appropriate decisions on the need for preventive services. Currently, interest is focused on microbiological assays of Streptococcus mutans and Lactobacilli (126-129). Attempts are being made to develop microbiological tests which are practical in the field or clinical settings (130-134).

Partial results from four studies, which either reported the predictive values of the microbiological assays or, which contained data from which they could be calculated, are shown in Table 11.3. Crossner (135) found high predictive values from Lactobacillus counts alone and was able to increase the negative predictive value to .91 by combining the assay with a measure of preceding caries. Honkala et al.(136) did not find high positive values when they measured Lactobacillus counts in relationship to the previous two-year caries experience. Newbrun et al.(137) found even lower positive predictive values when they related Streptococcus test scores to the preceding four-year caries experience. Such high negative predictive values may serve to screen out those who are not likely to experience caries and, therefore, not need expensive preventive therapy. However, Steckson-Blicks' S. mutans test in a prospective

TABLE 11.3

PREDICTIVE VALUES OF MICROBIOLOGICAL ASSAYS IN CARIES TESTS

		Sample						Predictive Values[1] for New Decay			
	Setting	Age	Size	Caries Increment	Per cent with No Increment	Duration	Test				
Crossner 1981 (135)	Orebro Sweden	14	115	1.26	42.6	64 weeks		PPV^a		NPV^a	
							Lactobacillus	.85		.80	
							Lactobacillus and 33 week caries activity	.67		.91	
Honkala et al. 1984 (136)	Kuopio Finland	13	153	?	47.6	2 yrs. (retrospective data)		Girls		Boys	
								PPV^b	NPV^b	PPV^b	NPV^b
							Dentocult Lactobacillus	.42	.81	.38	.88
Newbrun et al. 1984 (137	Tallahassee Florida	5th & 6th grade	293	?	41% had 0-1 caries increments over 4 previous years	4 yrs. (retrospective data)	S. Mutans MSBB	PPV^c		NPV^c	
							2	.11		.97	
							3	.11		.96	
							4	.14		.96	
							5	.14		.95	
Stecksen-Blicks 1985 (138)	Omea Sweden	8 13	88 91	1.5/yr 3.7/yr	43% 37%	1 yr. 1 yr.		8-yr-olds		13-yr-olds	
								PPV^a	NPV^a	PPV^a	NPV^a
							Lactobacillus	.44	.86	.61	.73
							S. Mutans	.40	.90	.51	.73
							Combined	.58	.86	.72	.71

Note: 1) PPV = Positive predictive value
NPV = Negative predictive value
2a) for 3 or more lesions
b) for 2 or more lesions
c) for 8 or more lesions

study was not as negatively predictive (138). Combining the S. mutans test with a Lactobacillus test improved the positive predictive value for 13-year-olds to 0.72. Burt et al.(139) measured S. mutans and caries in the fissures of lower first permanent molars over five cycles in a two-year study. Only 23 per cent of those with consistently high counts became carious, whereas 97 per cent of those with consistently low counts remained sound. However, about one-third of the teeth had fluctuating patterns of S. mutans counts.

These tests may hold promise of utility in dentistry, especially when the predictive values are over 0.9. The encouraging results of Newbrun et al. need to be verified in a prospective trial and where the disease incidence is higher.

3. Is there evidence that early diagnosis and prompt treatment improve prognosis?

There are no randomized trials that have evaluated this. Assuming that regular attenders would demonstrate any benefit that early detection provides, studies which have assessed both dental health status and regularity of attendance were examined in Table 11.4. Since the studies were cross-sectional or prospective, the problem of regular attenders being systematically different from the irregular attenders (140-142), can not be controlled.

Most of these studies, shown in Table 11.4, reported health outcomes in terms of caries scores using the components of decayed (D), missing (M) and filled (F) teeth (T). Typical is the study by Eddie et al.(143) where regular attenders were seen to have had higher caries (DMFT) and filled teeth (FT) scores and fewer missing teeth (MT). This pattern is consistent with the cross-sectional findings by Cutress et al.(144) and Todd et al.(145) who found those who reported regular attendance also had fewer decayed teeth (DT). A greater per cent of regular attending young adults in both England and Wales had sound or filled lower right first permanent molars than did their irregularly attending cohorts (146). Self-reported oral health status was better among adult regular attenders in a Danish study (140).

In contrast, regular attenders among Finnish children had slightly higher missing teeth (MT) scores than either irregular or non-attenders (147).

Among rural elderly Iowans (148), the recency of the last dental visit related well to the retention of teeth. However, the relationship of the recency of the last visit to lifetime behaviours was not examined and, secondly, the edentulous status may be the "cause" of the infrequent visiting rather than the "result" (149).

A further study of the dentate Scots (143) was reported by Nuttall (150). Five-year dental service records, obtained from the General Dental Service, were compared for frequent (visiting at least once each year) and infrequent visitors. Frequent visitors received more, especially repeated, fillings and scalings. Frequent attenders had 0.81 fewer extractions over the five years.

A unique study was conducted among 2000 low-income people attending a newly opened clinic in the Netherlands (151). The Dutch dental insurance system requires people to maintain regular attendance or lose their eligibility for free dental benefits. Thus, these people's regularity of attendance was substantiated by more than self-reports and the status and needs were measured in a clinical setting. The differences between regular and irregular attenders for males and females are less clear than the results obtained from surveys. There were no significant differences between many health status indicators although irregular attenders did need more extractions. However, only female regular attenders required less care, as measured by relative value units (RVUs), and even they required 11.21 RVUs or nearly three hours of treatment. While evidence from cross-sectional studies such as this is of a low level, the benefits of early detection, as defined by regular (every six

TABLE 11.4

DENTAL HEALTH EFFECTS OF REGULAR VISITS TO DENTISTS

	Location	Sample	Age	N	Outcome			
Todd et al. 1975 (145)	England	Representative survey	14	?	Tooth Caries Scores in Children by Regularity of Visits			
						Visits		
						Irregular	Regular	
					DMFT	6.9	8.1	
					D	2.9	1.3	
					M	1.0	0.7	
					F	3.3	6.1	
Todd et al. 1980 (146)	England and Wales	Representative survey	16-34	1075	Per cent of Young Adults with Sound or Filled Lower Right First Permanent Molars by Regularity of Dental Visits			
						Irregular	Regular	
					England	43	60	
					Wales	39	47	
Cutress et al. 1979 (144)	New Zealand	Representative survey	Adults	2068	Tooth Caries Scores by Regular Dentist at Age 45-54			
						No regular dentist	Regular dentist	
					Number	231	238	
					DMFT	25.4	20.2	
					DT	0.5	0.7	
					MT	23.8	8.8	
					FT	1.1	10.7	
Millen et al. 1981 (147)	Finland	Representative survey	6-8	1332	Tooth Caries Scores in Children by Regularity of Dental Visits			
						Annual Check-up		
						None	Occasional	Regular
					dt	2.9	2.6	2.3
					ft	2.8	3.6	3.9
					mt	0.3	0.4	0.5
					dmft	5.5	6.0	5.8

TABLE 11.4 (Con't)

DENTAL HEALTH EFFECTS OF REGULAR VISITS TO DENTISTS

Swallow et al. 1981 (151)	Holland	New clinic attenders	15-64 most 15-34	2000

Dental Status and Needs of Regular and Irregular Attenders by Sex

	Males		Females	
	Regular	Irregular	Regular	Irregular
Sound teeth	13.6	13.0	12.5	11.9
Missing teeth	7.7	8.8	9.1	10.4
Extractions Req'd	0.20	0.75*	0.27	1.28*
RVU Req'd	14.35	14.57	11.21	14.28*

* statistically different from regular attenders

Petersen 1983 (140)	Denmark	Representative survey	20-69	5960

Per cent of Adults Reporting Self-Assessment of Dental Status by Regularity of Dental Visiting

	Visiting		
	Never	Irregular	Regular
Has no or few teeth; with dentures	74	53	11
Has own teeth with few cavities or filling	4	20	50

Eddie 1984 (143)	Scotland	Dentate from national survey	Adults	720

Tooth Caries Scores by Regularity of Dental Visiting Over 5 Subsequent Years

	Check-ups	
	None or Infrequent	Yearly
Per cent visiting	84	16
DMFT	20.3	21.8
FT	5.2	12.8
MT	12.3	7.8

Nuttall 1984 (150)	Scotland	Prospective study of dentate	Adults	720

Number of Services Provided by Frequency of Dental Visiting Over 5 Years

Visiting:	Infrequent	Frequent
Courses of treatment	2.7	7.3
Filled tooth surfaces	9.5	18.4
Scalings	1.3	4.2
Extracted teeth	1.4	0.6

Hunt et al. 1985 (148)	Iowa	Census Survey	65+	3673

Dental Status by Recency of Last Dental Visit % Distribution

	5+ yrs.	3-5 yrs.	1-3 yrs.	6-12 mos.	< 6 mos.
Dentate 2 arches	7	8	20	23	42
Dentate 1 arch	21	15	20	16	28
Edentulous 2 arches	70	11	10	4	6

months) attendance, were not dramatic and for the ultimate criteria, lost teeth were not evident.

4. Is there evidence that the benefits of early detection are greater than the costs?

The value that the public places on the benefits of early treatment versus later treatment of dental caries is not known. In a research setting that involved paired preference choices between patient records, dentists themselves appear to place little value on the difference between a sound tooth versus one that is restored (presumably even if it were extensively restored) as this difference did not enter the regression equation used to derive a new oral health status index based on dentists' preferences (93,94). The Marcus et al.(94) index was sensitive enough to detect differences in preferences between sound (or well-restored) teeth versus teeth that are decayed (and untreated) and between teeth with medium versus deep periodontal pockets. The major benefit of dental care, as judged by these dentists, is avoiding deep periodontal pockets and missing teeth.

The patients who seek care may be seeking: relief from pain or from a loose tooth; removal of stains and tartar or, treatment for sore or bleeding gums (152). To the extent that the early detection of caries removes the threat of those conditions, then the public is willing to pay for such early detection. However, these kinds of benefits were not measured in the studies described. Thus, three problems arise. The benefits of early detection are difficult to assess and, secondly, are difficult to demonstrate given the weakness of the literature. Further, what benefits there are have not been quantified in terms that can be related to costs. Therefore, again one must conclude that there is an absence of evidence that the beuefits of early caries detection are greater than the costs.

5. Is the benefit/cost ratio of early detection of caries greater than the benefit/cost ratio for other programs?

As with periodontal disease, this is an area in which there are no data. One can not calculate the benefit/cost ratio of early detection and compare it to later detection let alone compare such a ratio against other programs.

The 1979 (2) review concluded that there was no scientific or evidential basis to alter current practices even though the authors suggested that "... examination intervals greater than six or even 12 months may be acceptable for some, and perhaps many people". One author sees this ambiguous situation as justification for frequent surveillance and retention of the six-month visit (153,154). Nonetheless, some recently signed Ontario dental insurance contracts have mandated that recall examinations will only be paid at intervals of nine months or greater (155).

11.7 SUMMARY AND RECOMMENDATIONS

This current review has pointed out the many deficiencies in the required information on which reasonable recommendations or recall examinations can be made.

Nonetheless, the following conclusions seem appropriate:

1. The epidemiology of dental diseases is changing but the extent of change in Canadian populations is not well documented, particularly in longitudinal studies. If United States' evidence holds for Canadian children, a given child is unlikely to have any new enamel cavitation in the next year and for those that do succumb, the caries is likely to be in a pit or fissure and very slowly progressive. In adults, root caries is related to the occurrence of root recession and, in the opinion of Burt (103), may be controlled either by effective periodontal disease prevention or the same background levels of fluorides that are responsible for the inhibition and reversal of early enamel lesions. Periodontal disease levels for Canadians are already the best among international comparisons and may be improving. More precise definitions of disease and longitudinal studies of representative populations are likely to

show that few Canadians have severe or active disease.

2. The efficacy of prevention and treatment methods are proven for enamel caries but the evidence is much less robust for periodontal disease.

3. Diagnostic tests used for enamel caries restoration are accurate if the later stages of the disease process are used as the diagnostic criterion. For enamel caries prevention, soon to be available microbiological assays hold promise in sorting out those unlikely to succumb to caries, thereby saving needless, expensive preventive therapies. In adult periodontal disease, active disease can not be accurately diagnosed with conventional tests.

4. The benefit of early detection, as compared to later detection of dental disease while apparently obvious to clinicians and patients, can not be conclusively demonstrated from the literature. Further, the benefit that might exist has not been put in terms that can be compared to costs.

5. The benefits of early detection can not be compared with the benefits of the same dollar invested in other programs.

6. There is no evidence from a controlled or prospective trial which supports any one interval of recall examination over another whether that interval be six, nine, 12 months or any other period.

   Thus, perfectly informed consumers, especially those with no new disease over the previous one or two years, could rationally choose to extend the recall interval beyond (and with continued good experience, well beyond) six months without prejudicing their health in appreciable ways.

Research Recommendations

1. Diagnostic tests, which can sort those with active periodontal disease from those without, need to be developed.

2. The natural history of periodontal disease and, to a lesser extent, dental caries, needs to be described in longitudinal studies for Canadian or comparable populations.

3. The benefits of dental care need to be established and defined in quantifiable terms.

4. Randomized trials to test the efficacy of different recall periods need to be conducted.

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